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The Sixty-First Meeting of the American Astronomical Society

By CHARLES H. SMILEY

At the invitation of Professors Jan Schilt and W. J. Eckert, the sixty-first meeting of the American Astronomical Society was held at Columbia University on Thursday and Friday, December 29 and 30, 1938. The efficient registration bureau maintained by Columbia University reported that 115 members and 43 guests attended the meeting. Most of the visitors stayed at the King's Crown Hotel or in the dormitory rooms which were made available to the astronomers. The weather was cold but fortunately only a thin covering of snow fell in the two days.

The meeting was opened by a welcoming address by Dr. Jan Schilt. Dr. Philip Fox, Vice-President, presided at the meeting in the absence of the President, Dr. R. G. Aitken. Altogether forty scientific papers were presented, maintaining a high standard of interest. Almost a third of the papers were presented by members of the staff of the Harvard College Observatory, including one by the director, Dr. Harlow Shapley, on the distribution of cluster-type Cepheids and the thickness of the Milky Way.

No attempt will be made here to mention all of the papers on the program. The reader is referred to the abstracts of the papers which will appear presently in the *Publications of the Society*. It may be mentioned, however, that H. N. Russell and Z. Kopal presented two very interesting theoretical papers on eclipsing variables, and one on the apsidal motion of binaries was presented by T. E. Sterne. Another group of papers concerned problems of the radiation and atmospheres of the sun and stars. Keivin Burns showed some splendid lunar photographs. These were followed by several papers on color-photographs of the lunar eclipse of November 7, 1938, and of star fields. E. C. Slipher of the Lowell Observatory presented some very interesting photographs of the twilight ring around Venus and discussed their meaning.

The photograph of the society was taken at noon on Thursday. One hundred twenty-eight persons appear in it and, thanks to the generous assistance of Dr. J. E. Merrill, only six persons remain unidentified. Following the taking of the photograph, the members lunched at the King's Crown Hotel.

After the session for papers on Thursday afternoon, Dr. and Mrs. Schilt entertained at tea in the Men's Faculty Club. In a pleasant atmosphere of informality, the members and guests of the society enjoyed

the stimulating conversations for which the organization is noted. Following the tea, Dr. Clyde Fisher and his staff entertained the group at the Hayden Planetarium. The visitors were shown the unusual conjunction of planets which occurred near the time of the birth of Christ. After precession had been demonstrated and the southern skies had been shown, many a teacher in the group found himself wishing that he had a planetarium at his disposal.

On Friday, lunch was served at the Men's Faculty Club and seating arrangements were a bit crowded when fifty per cent more people appeared than had indicated their intentions of coming. Eventually all were served and the group then returned to Pupin Hall for the afternoon session.

Many of the members took advantage of the opportunity to visit the Hollerith Computing Bureau where, under Dr. Eckert's expert direction, many of the tedious numerical operations necessary in research are being done by machinery with a minimum expenditure of human energy and time.

Dr. C. H. Smiley, acting as secretary in the absence of Dr. J. C. Duncan, announced that the following persons had been elected to membership in the society:

Lawrence Aller, Graduate Student, Harvard College Observatory, Cambridge, Massachusetts.

Jack Belzer, Assistant, Nautical Almanac Office, U. S. Naval Observatory, Washington, D. C.

Sylvan M. Bestul, Assistant Astronomer, U. S. Naval Observatory, Washington, D. C.

Miss Barbara Cherry, Assistant, Hayden Planetarium, New York City.

Frederick E. Ellis, A.A.V.S.O. Assistant, Harvard College Observatory, Cambridge, Massachusetts.

Charles A. Federer, Jr., Head of Junior Activities of the American Institute, 43 West 87th Street, New York City.

Leo G. Glasser, Graduate Student, Cornell University, Ithaca, New York.

Hans Georg Hertz, Fellow in Astronomy, Yale Observatory, New Haven, Connecticut.

Boris George Karpov, Instructor, Vassar College, Poughkeepsie, N. Y.

Dr. Zdenek Kopal, Research Associate, Harvard College Observatory, Cambridge, Massachusetts.

John E. Lancaster, New Canaan, Connecticut.

V. E. Maier, Goethe Link Observatory, Indianapolis, Indiana.

Dr. George Rosengarten, West Philadelphia High School and Philadelphia College of Science, Brookline, Delaware County, Pennsylvania.

Norman C. Seewald, Junior Astronomer, U. S. Naval Observatory, Washington, D. C.

Kaj Aage Gunnar Strand, Research Associate, Sproul Observatory, Swarthmore, Pennsylvania.

Gordon W. Wares, Graduate Student, Yerkes Observatory, Williams Bay, Wisconsin.

Dr. Alice H. Farnsworth presented a beautifully-worded motion, recording the appreciation of the society of the splendid hospitality of Professors Schilt and Eckert, Columbia University, Dr. Fisher and his

staff, Hayden Planetarium, and others who helped to make the meeting the great success that it was. This motion was carried by an enthusiastic unanimous vote.

The society dinner was held in the Men's Faculty Club on Friday evening, more than a hundred persons attending. The usual after-dinner speeches were dispensed with. Dr. Shapley spoke briefly of the difficult situation in which a number of German astronomers find themselves. He announced that Dr. Richard Prager, formerly of the Neubabelsberg Observatory, had been invited to come to Harvard and was expected before the summer.

At the invitation of Dr. R. G. Aitken, the next meeting of the society will be held at the University of California in Berkeley, California, next summer.

BROWN UNIVERSITY, JANUARY 7, 1939.

Report of Section D (Astronomy), American Association for the Advancement of Science

By HARLAN T. STETSON*

The Section for Astronomy (D) of the American Association for the Advancement of Science met at Richmond during the annual winter meeting of the Association on December 27 and 28, 1938. The opening meeting was a joint session with Section E (Geology) for the purpose of a symposium on problems of mutual interest to astronomers and geologists. The earth is after all a planet in the solar system and there are many problems of the earth sciences that obviously cross the field of astronomy. The interpretation of recent geophysical observations relative to the nature of continental structure entails the question of land movements which structural geologists believe are still taking place. The importance of geodetic measurements with the highest order of accuracy in detecting variations in geographic coördinates was stressed as a possible astronomical contribution to fundamental questions raised by geologists and geophysicists. The symposium was arranged with the coöperation of the American Geophysical Union and was particularly timely in view of the coming Seventh Assembly of the International Union of Geodesy and Geophysics in Washington next September.

Wednesday was devoted to sessions of the more strictly astronomical papers. The Wednesday morning session opened with a comprehensive paper giving the results of long studies of the Cepheid problem by William Luby of the University of Kansas City. Papers of astrometric interest were presented by members of the staff of the Naval Observatory

*Secretary of Section D of the A.A.A.S.

and of the Leander McCormick Observatory. Dr. H. R. Morgan and F. R. Scott discussed new determinations of the mass of the moon and the mass of Venus from observations of the sun. The morning session was closed with the address of the retiring vice-president of the Section, Dr. Philip Fox of the Museum of Science and Industry, Chicago. Under the title "Astronomers and Their Tools," Dr. Fox reviewed the great advancement astronomy and astronomical instruments have made from the earliest time to the present day.

During Wednesday afternoon important contributions were presented relative to the study of parallaxes from the McCormick Observatory and a discussion of the absolute magnitudes derived from the McCormick parallaxes. Professor S. A. Mitchell, C. M. Anderson, and D. Reuyl participated. A discussion of visual and photo-visual magnitudes was raised through the presentation of papers by Professor Mitchell and C. A. Wirtanen. Again fundamental astronomy was represented by contributions from the Naval Observatory. "The Form of the Solar Energy Curve between 8μ and 14μ" by Arthur Adel was a welcome contribution from the Lowell Observatory. This supplemented the important paper announcing the discovery of nitrogen pentoxide as revealed by the remote infra-red telluric spectrum announced at the Indianapolis meeting of the American Association last winter. The sunspot cycle came in for discussion by C. N. Anderson of the Bell Telephone Laboratories.

The Section D dinner was held on the evening of December 27 at the Jefferson Hotel. A display of the work of the Leander McCormick Observatory was included among the exhibits in the exhibition hall. It was a significant presentation of some of the important scientific work being carried on in Virginia. At the invitation of Professor Mitchell, those attending Section D were invited to visit the Leander McCormick Observatory during the meetings of the Association.

The Vice-President and Chairman of the Section, Dr. R. Meldrum Stewart of the Dominion Observatory, presided at the sessions. The Secretary is indebted to Dr. H. R. Morgan, who was appointed acting secretary for the Richmond meeting, for his assistance in reporting the activities of the section.

THE LEONIDS (In 1833?)

My dad, he used to tell us kids
About a shower of Leonids.
He didn't call them by that name,
And no one called them—they just came!
Dad said it was a bully show,
A real star blizzard, stars for snow.
Loose stars a-scooting everywhere
Gave folks a sure gosh-awful scare,
Dad said—not I. *I* wasn't there!

EMMA J. C. DAVIS
(In the *Los Angeles Times*)

Ernest William Brown
1866-1938

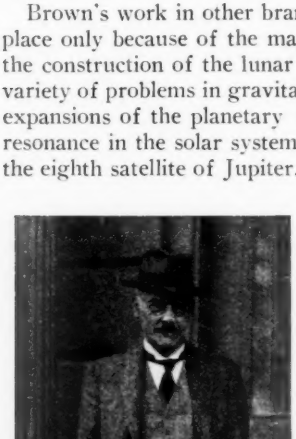
By W. J. ECKERT

The president of the International Astronomical Union remarked at a meeting of the general assembly in Paris that the moon belonged to Brown. A less concise statement would be that Brown's theory of the motion of the moon and the tables based on it constitute one of the scientific achievements not only of our time but of the whole history of celestial mechanics. The completeness and accuracy of this theory is such as to eclipse all previous theories and to satisfy the needs of observation for years to come. No doubt corrections will be made here and there, but a general reworking of the theory is certainly not necessary.

It is now thirty years since the theory was completed and fifteen since the tables were adopted, and each year has brought new confirmation of their excellence. One of the most striking of these occurred in 1926 when he was able to show that an important difference between theory and observation was due not to the erratic behavior of the moon but to unpredicted changes in the rate of the rotation of the earth. This thesis is now generally accepted. The latest confirmation came during the past year when the writer completed a numerical verification of the main part of the theory. This verification showed that Brown's work was practically without error, and that the additional accuracy where needed could be readily obtained.

Brown's Lunar Theory was not completed in a day, but was the result of almost a lifetime of concentration on a single problem. From the time he was a student at Cambridge until his death, he was interested in some phase of the problem. He began in 1888 by reading a paper by G. W. Hill outlining a new method of solution. From then until 1895 he spent most of his time examining the mathematics of the lunar theory. During that period he made many contributions to the subject. His "Introduction to the Lunar Theory" containing a critical examination of the various methods available appeared in 1896. The systematic calculation of the coefficients of his theory occupied his attention until 1908. Then came the preparation of the tables and the determination of the constants from observation. The tables were published in 1919 and since 1923 have been used for the computation of the positions of the moon given in the national ephemerides. In order to secure better observational material, he organized a campaign for the observation and reduction of occultations. In the last few years of his life he turned his attention again to the foundations of the lunar theory, and his last paper contained a revised form of the equations of motion of the moon with a discussion of the accuracy lost by the presence of small divisors. This paper was sent to the printer two days before he died.

Brown's work in other branches of celestial mechanics takes second place only because of the magnitude of his work on the moon. After the construction of the lunar tables was well in hand he worked on a variety of problems in gravitational astronomy such as the equations and expansions of the planetary theory, the Trojan Group of asteroids, resonance in the solar system, the stellar problem of three bodies, and the eighth satellite of Jupiter. Much of this work is summarized in his book"Planetary Theory"written in collaboration with Professor C. A. Shook. The work on the Stellar Problem of Three Bodies which was done after he retired from "active" work gave a satisfactory solution to a problem which had been attempted many times before.



ERNEST WILLIAM BROWN
1866-1938

The appreciation of Brown's scientific work is not confined to the International Astronomical Union, but extends to amateurs the world over. He was one of the few scientists who had a popular following, not because of his popular writing but because his scientific work had in itself a popular appeal. The solar eclipse of 1925 made the results of his work known to millions, and his occultation campaign has made him familiar to many serious amateurs. He attended the meetings of the A. A. V. S. O. with as much faithfulness as those of the National Academy.

It is difficult to examine Brown's lunar theory without pausing to speculate about the factors which made such a work possible. There is no doubt that he had great native mathematical ability and that it was developed at an early age by the English system of education. He was thus able at the age of twenty-one to read Hill's paper and to begin productive work. He himself considered his early training in solving problems an important factor, and felt it a great pity that this type of preparation had been replaced in American colleges. The early start, however, was necessary but not sufficient. The other requirements were thoroughness and concentration. For the next thirty years it was the moon which received his first attntion.

Brown's own opinion of his scientific work was extremely modest. I

have often heard him boast about his accomplishments in agriculture or art, but seldom about his scientific work. He once told me that of course he was a "good man of science" but not a "great scientist."

It is difficult for one who knew him only twelve years to write about his earlier life because he seldom talked about himself. We know, however, that his childhood ambition was to be a musician, but that his practical father persuaded him to give up the idea. Another interesting sidelight is that he read Hill's paper not at the suggestion of J. C. Adams, who was writing on the same subject as Hill, but at the suggestion of George Darwin. He often spoke of Darwin as a "sort of godfather," and an important part of his later visits to England were the visits with Lady Darwin.

Christopher Morley has paid tribute to Brown's fondness for children and of theirs for him in an article in the *Saturday Review of Literature* under the title "Gratitude, Forty Years Late." The time may have been forty years ago or four and the child Christopher or Suzie or one of the many in between. The description applies equally well. To quote from Morley's article: "Professor E. W. Brown, emeritus professor of Yale University, distinguished mathematician and astronomer, has long since forgotten the matter, but it touched my life more than the researches in celestial mechanics and the Tables of the Motions of the Moon which made him F.R.S. and for which he is known to science. The conjunction (or asymptote) this month of Children's Book Week and Bicky Brown's 70th birthday seems to me quite as important as any of his calculated Inequalities in the Moon's Motion Due to Direct Action of the Planets. Why, in childhood, I knew Prof. Brown as 'Bicky' is now forgotten, but I hope he is still so addressed by his intimates, and I am quite sure that Dianna herself thinks of him by that familiarity . . . In the family where he was a sort of adopted bachelor uncle, some of the best books the children ever had were given by him at Christmas and birthdays between (say) the ages of four and fourteen." During the forty years from instructor at Haverford to emeritus professor the principal change as far as the children were concerned was from "Bicky" to "Unky."

Since 1914 the small farm at Salem, Connecticut, was one of his chief sources of pleasure. This natural beauty spot was maintained in great simplicity. He derived considerable satisfaction from the fact that in the twenty years he had owned it, the principal outlay in its maintenance was ingenuity. The many astronomers who have enjoyed a picnic at the pond will testify to its charm.

In closing it might be permitted to give two intimate glimpses of Professor Brown: one among my first and the other among the last. The first was his daily schedule at the time of my first visit to the farm:

A. M.
3:00—Celestial mechanics and coffee
7:30—Breakfast

8:00—Work in the garden or about the farm
P. M.
12:00—Lunch
1:00—Light reading in bed
4:00—Tea
6:00—Dinner at the home of a friend
9:00—To bed

and this was his vacation schedule. The other picture is typical of the occasions when I consulted him during the work on the verification of the lunar theory. Even though he was very ill at the time, an inquiry concerning a particular term in his theory would be answered from memory. He would state precisely the origin of the various components, the accuracy with which each was known, and the approximate value of the final coefficient. These questions concerned work which he had completed thirty years before.

Theoretical Problems of Stellar Absorption Lines

By DONALD H. MENZEL

(Continued from page 22)

(6) *Profiles of Absorption Lines.* Two alternative formulae, (4.5) and (4.6), have already been given for the profiles of absorption lines. Because of inadequacy of the atmospheric model, neither expression is satisfactory. The greatest discrepancies, as has been mentioned, occur for the centers of the lines.

Woolley has called attention to the fact that cyclic transitions involving the continuum will tend to raise the theoretical intensities at the line center. To take into account, partially at least, the interlocking effects of continuous and discrete levels, Woolley integrates over the former, from a given series limit, and treats the continuum as a single discrete level. As far as the equations of statistical equilibrium are concerned, the procedure is quite satisfactory. There will obviously be difficulties in deriving, by such a method, the distribution of energy in the spectrum of a star.

There is one obvious way in which Woolley's approach can be improved. In considering the Balmer series, for example, he would consider the quantum levels 1, 2, and 3, and then, disregarding levels $4 - \infty$, he would count as level 4 the integrated continuum. The indicated continuity of discrete and continuous levels would have been better preserved by supposing the neglected discrete levels to be broadened and then included as part of the continuum.

In the general equations of transfer no special relationships are need-

ed to account for the occurrence of emission lines. As a result of the solution, with the minute departure from thermodynamic equilibrium, we shall find that the b_n's not only differ from unity but they will generally show a uniform progression with quantum number, finally fulfilling the condition (5.12). If n and n' denote upper and lower levels we see that when

$$b_n > b_{n'},$$

the line will tend to form in emission. If

$$b_n < b_{n'},$$

an absorption line will result.

As has been pointed out, the b_n's prove to be surprisingly close to unity. The greatest departures usually occur for the lower values of n. For ordinary electron temperatures, b_n will generally be less than unity if the exciting star is supposed to be lacking in Lyman line radiation. When the Lyman line radiation from the exciting star has its equilibrium black-body value, b_n is greater than unity and decreases slowly to unity at the series limit. When the former of the two above conditions prevails, Lyman emission lines are formed, as in a gaseous nebula or star with extended atmosphere. When the latter condition prevails, absorption lines are produced. It follows that, even for planetary nebulae, infinitely black Lyman absorption lines cannot be produced. The postulate made by Zanstra that all the Lyman line radiation, as well as that in the Lyman continuum, is depleted to form the Lyman alpha and higher series quanta is an extreme that can obtain only when the effective ionization or the electron temperature approaches zero.

For most of the cases most likely to occur in nature the approximation

$$b_n = b_{n+1}$$

is a good one. It is, therefore, quite "touch and go" whether the first line in any series will appear in absorption or emission. *Hα*, for example, often appears in emission when later series members appear in absorption, as in the spectrum of *α* Cygni.

The reasoning advanced in this section will be recognized as the most general case of "interlocking." What does not seem to have been previously pointed out is that all the effects, interlocking, collisions, etc., represent a return to the viewpoint (b) expressed by Eddington. It turns out that the second viewpoint is much closer to the truth than (a), which is representative of the condition of monochromatic radiative equilibrium. The applications of these equations are numerous; it seems likely that even such extreme cases as the presence of Balmer emission in long-period variables can be explained as an effect of temperature gradient coupled with the presence of cyclic processes.

As a first approximation, then, we may expect to account for the distribution of spectral energy, within absorption lines as well as continuum, by setting up the optical depth as a continuous function of the frequency ν:

$$\tau = \int_x^\infty N\, a(\nu) dx = a. \tag{1}$$

The constant a, which defines the optical depth of the effective photosphere, will lie somewhere between ⅓ and 1. We may regard (1) as defining x, the level of the effective photosphere, as a function of ν. In transparent regions of the spectrum x will lie deep in the atmosphere; in opaque spectral regions, as near a line center, the effective photosphere will be at high levels. We shall suppose (1) to be solved so that

$$x = f(\nu). \tag{2}$$

A schematic graph of such a function is shown in Figure 7, for a hypothetical A-type star. Allowance has been made for the continuity near the series limit.

We shall now postulate the existence of a temperature gradient in the atmosphere, so that the temperature is a function of x:

$$T = \phi(x). \tag{3}$$

Or, because of (2), we may regard T to be a function of ν,—a different

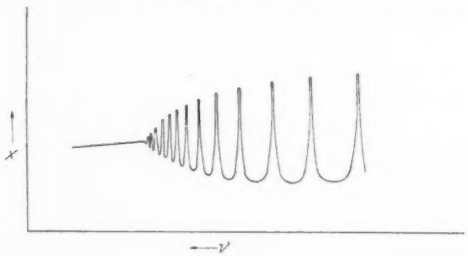


FIGURE 7

Height (x) above photosphere, where the optical depths at various frequencies approach the value unity.

effective temperature for each frequency. We shall indicate this by writing $T(\nu)$. The emission of the star at a given frequency will be proportional to the value defined by Planck's law:

$$E(\nu)d\nu \propto \frac{2\pi h\nu^3}{c^2} (e^{h\nu/kT(\nu)} - 1)^{-1} d\nu. \tag{4}$$

When $T(\nu)$ is a constant, (4) gives the ordinary black-body law. When $T(\nu)$ is defined by a relationship like that shown in Figure 7, the spectral distribution of the emitted radiation will appear somewhat as in the microphotometer tracing, Figure 8, of the A-type star, γ Ursae Majoris. The unknown Stark effect of high series members introduces complications and makes it impossible to predict the function schematically indicated by equation (3). This is unfortunate because if (3) could be defined, we should then be able to determine, directly from the observational data, the temperature as a function of level.

To indicate the nature of the calculations, let us assume that for some line of the Balmer series, the coefficient of absorption at the line center is ten times that in the wings. The radiation from the line center comes from a higher and cooler atmospheric layer than does the radiation from the wings; an estimate of the relative intensity, center to wing, shows

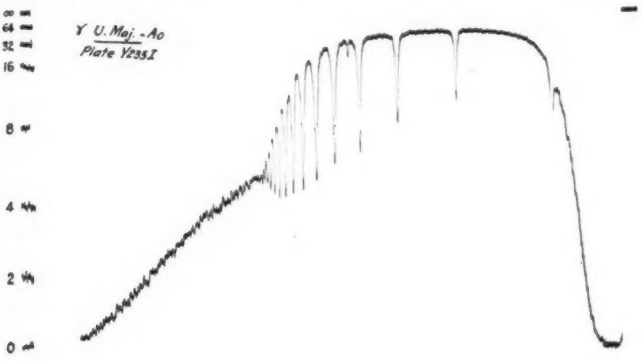


FIGURE 8
MICROPHOTOMETER TRACING BY C. S. YÜ.
Lick Observatory.

that the equivalent black-body temperatures of the two layers differ by about 2000°. If the star's surface gravity is g, the mean temperature $\bar{T}$, and $\bar{m}$ the mean atomic weight, the approximate difference, Δx, between the levels corresponding to line wing and center is

$$e^{\bar{m}g\Delta x/k\bar{T}} \sim 10, \tag{5}$$

or, for $g = 10^3$, $\bar{m} = 1.6 \times 10^{-24}$, and $\bar{T} = 10^4$,

$$\Delta x \sim 2 \times 10^9 \text{ cm}. \tag{6}$$

The temperature gradient proves to be of the order of 10^{-1} deg. per km. The numbers here given are merely illustrative; for the sun the gradient is probably higher.

The problem of the intensity distribution within the Balmer continuum is seen to be of the same character as the problem of central intensities of spectral lines. Very few persons have dealt specifically with the problem from the theoretical viewpoint. Apparently, however, the opinion of investigators has been that the dip beyond the Balmer limit is small because the optical depth (referred to an effective photosphere at a frequency well to the red of the limit) is much less than unity. With that viewpoint, at least for A-type stars, I seriously disagree. The relative optical depths may differ by fully a factor of 100 and I regard the spectral distribution as characteristic of the temperature of the effective photosphere.

In discussing the continuum, under §(5), we found it necessary to

discuss line absorption. Analogously, in the present section, we have been forced to consider atomic processes involving the continuum. These necessities further illustrate the fact that discrete and continuous processes are closely coupled. Several years ago, Pannekoek attempted to explain certain anomalies in the spectral distribution of stellar radiation in terms of sharp discontinuities beyond the heads of various series limits. By neglecting the continuity of the line and continuous spectra, he greatly overestimates the magnitude of the effect.

The discussion presented in this section tends to leave the problem of line profiles in a very chaotic state. We have emphasized the importance of temperature gradient. Yet if this were the only factor, the presence of emission lines in early members of a spectral series would imply the existence of a *negative* gradient. In the chromosphere we find concrete proof that *negative* gradients do sometimes occur, but emission lines cannot always be attributed to the effect of such an anomaly. General scattering and interlocking, with the attendant possibilities of cyclic processes, must be taken into account. For the present, the whole problem of line profiles—observationally as well as theoretically—seems to be at an *impasse*.

(7) *Curves of Growth.* Because of various difficulties, some of which have been listed in the previous section, study of the details of line profiles has been largely and successfully superseded by study of total absorption. Theoretical difficulties, especially with the centers of profiles, have only a minor influence on the total absorption. The value of the line intensity is governed chiefly by the position and character of the line wings, where the optical depth, $\tau(\nu)$, is small. Theories differing as widely as those that give rise to equations 4.5 and 4.6, for small values of the optical depth, give the same expression to the first order in $\tau(\nu)$, *viz.*:

$$r(\nu) \sim 1 - \tau(\nu) + \text{terms in higher powers.} \qquad (1)$$

The intensity of the absorption line is ordinarily expressed as the width, in frequency or in wave-length units, of a line of rectangular pro-

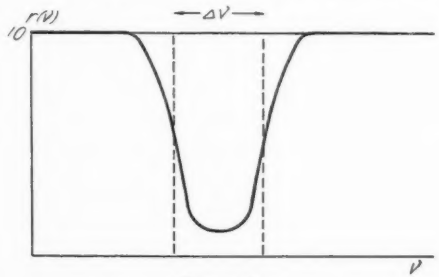


FIGURE 9

file, zero central intensity, and area equal to that of the true line. Figure

9. The equivalent width, $\Delta\nu$, in frequency units is

$$\Delta\nu = \int_0^\infty [1 - r(\nu)]\,d\nu = \int_0^\infty \frac{\tau(\nu)}{1+\tau(\nu)}\,d\nu, \tag{2}$$

where we have adopted the Schuster-Schwarzschild formula for the line profile.

Let N be the number of atoms, per cm² column above the photosphere, active in producing the absorption line. Then $\tau(\nu)$ is

$$\tau(\nu) = Na(\nu) = X[e^{-c^2(\nu-\nu_0)^2/\pi^2\nu_0^2} + (\pi^{1/2}\nu\nu_0/c)(\Gamma/4\pi^2)(\nu-\nu_0)^{-2}], \tag{3}$$

from (1.6). X, the optical depth at the line center, is given by:

$$X = N\frac{\pi e^2}{mc} f \frac{c}{\pi^{1/2}\nu\nu_0}. \tag{4}$$

Equation (3) is subject to the same restriction as (1.6), *viz.*, that the second term is employed only in the far wings of the line. Let

$$\frac{c}{v}\frac{(\nu-\nu_0)}{\nu_0} = p, \qquad \frac{c}{v}\frac{d\nu}{\nu_0} = dp. \tag{5}$$

Then (2) becomes

$$\Delta\nu/\nu = (2v/c)\int_0^\infty \frac{dp}{1+[X(e^{-p^2} + (c/v\nu_0)(\Gamma/4\pi^{3/2})(1/p^2)]^{-1}}, \tag{6}$$

which may also be set equal to W/λ, where W is the equivalent width in wave-length units and λ is the wave-length.

When $X<1$, the second term in the brackets of (6) may be neglected. Expand the denominator and we have

$$W/\lambda = \Delta\nu/\nu = (2v/c)\int_0^\infty (Xe^{-p^2} - X^2e^{-2p^2} + X^3e^{-3p^2} \ldots)\,dp$$

$$= (\pi^{1/2}vX/c)\,(1 - X/\sqrt{2} + X^2/\sqrt{3} \ldots). \tag{7}$$

When $X>1$, but not so large that wing damping must be considered, the integral becomes

$$W/\lambda = (2v/c)\int_0^\infty dp/(e^{p^2}/X + 1). \tag{8}$$

The value of the integrand is essentially unity until p takes a value p' such that

$$e^{p'^2} \sim X \tag{9}$$

or*

$$p' \sim [\ln X]^{1/2}. \tag{10}$$

For values of $p>p'$, the value of the integrand falls rapidly to zero. Hence we may write, approximately,

$$W/\lambda \sim 2(v/c)p' = 2(v/c)[\ln X]^{1/2}. \tag{11}$$

*Logarithms to the base 10 are here denoted by the symbol, log. Natural logarithms are indicated by ln.

The integral appearing in (8) is a familiar one in quantum mechanics. Its value, more accurately expressed in terms of an asymptotic series valid only when $\ln X >> 1$, is

$$\frac{W}{\lambda} = \frac{2v}{c}(\ln X)^{\frac{1}{2}}[1 - (\pi^2/24\ln^2 X) - (7\pi^4/384\ln^4 X) \ldots] . \quad (12)$$

When X is so large that the integrand in (6) retains the value unity until the second or damping term of the integral comes into play, we may write

$$\frac{W}{\lambda} = \frac{2v}{c}\int_0^\infty \frac{dp}{1 + (Xc/v\nu \cdot \Gamma/4\pi^{3/2})^{-1}p^2} . \quad (13)$$

We no longer need consider the term in e^{p^2} since the term in p^2 gives quite as satisfactory a representation of the value of the integrand, *i.e.*, unity, over the line center. Carrying out the integration, we find:

$$W/\lambda = (\pi^{1/4}/2)(v/c)^{\frac{1}{2}}(X\Gamma/\nu)^{\frac{1}{2}}. \quad (14)$$

For values of X intermediate between those represented by (7) and (12) or by (12) and (14), the integration of (6) is best checked by quadratures.

There are several alternative ways of plotting the theoretical results. The one most commonly used involves the plotting of $\log W$ against the parameter $\log Nf$. This procedure was suggested by the fact that, when the value of X from (4) is substituted in (7) (first term only) or in (14), we have the two limiting cases:

$$\log W \sim \log Nf + \log \pi e^2/mc + 2\log\lambda - \log c + 8 \quad (15)$$

and

$$\log W \sim \tfrac{1}{2}\log Nf + \tfrac{1}{2}\log(\pi e^2/mc)\,\Gamma + 2\log\lambda - \log 2c + 8. \quad (16)$$

The term (8) is from the factor that converts W from cms to Angstrom units. Both (15) and (16) are linear with $\log Nf$, the former with slope unity and the latter with slope ½. The position of these lines is independent of the velocity parameter, v. The formula representing the transition region between the two linear regions becomes for large $\ln X$,

$$\log W = \log\lambda + \log(2v/c) + \tfrac{1}{2}\log[\ln Nf\,(\pi e^2/mc)(\lambda/\pi^{\frac{1}{2}}v)]. \quad (17)$$

A plot of the complete function of W, as dependent on Nf, is called a curve of growth. We note, first of all, that a single curve of growth cannot be used to depict the relationships at various wave-lengths. In Figure 10, we have plotted two hypothetical curves for two lines having the same values of v and Γ but of different λ. The diagram shows how W increases with Nf. The curve for 6000 A lies higher than that for 3000 A, with the transition or Doppler portion shifted only about half as much as the extremes.

These curves are most frequently determined from multiplet data. As has been previously pointed out in §(1), the f's are atomic constants, which can be theoretically predicted in certain cases. Suppose, for example, that we have two multiplets of iron, one at 3000 A and the other

at 6000 A. The plot of the logarithms of the equivalent widths of these lines against logarithms of the theoretical intensities should define the two curves of growth, as shown in Figure 10, provided, of course, that the lines cover a sufficient range of intensity. (Ordinarily, from a single multiplet, we obtain only a fraction of the curve of growth.) Various multiplets, for which the log Nf scale is subject to an additional con-

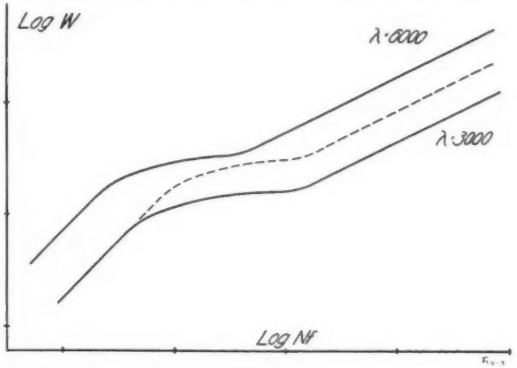


FIGURE 10

stant, may be superposed by sliding the curves in a horizontal direction. This procedure is theoretically sound, provided lines associated with the same v, Γ, and λ are used. We are never sure of the value of Γ, and the damping portion of the curve is always subject, in consequence, to considerable uncertainties. The diagram (10) also shows the danger resulting from the common practice of combining curves from different spectral regions. The 6000 A curve has been slid parallel to the log Nf axis to bring the two forty-five-degree portions into coincidence. It is obvious, from the lack of agreement, that serious errors may result from combining, according to the usual procedure, curves of growth for different wave-length regions.

In certain rare astrophysical cases, *e.g.*, for the sun, the observational data are sufficiently abundant to permit determination of curves of growth for rather narrow wave-length intervals. Allen, who attempted to analyze his extensive measures of equivalent widths of the Fraunhofer lines by means of diagrams like those of Figure 10, found that curves from different wave-length ranges could not be made to coincide. He further noted, empirically, that agreement ensued when one plotted, instead of log W, log W/λ, as a function of Nf. Allen's empirical discovery proves to be quite in accord with the derived equations (7-14). A much more symmetrical diagram is secured by plotting the logarithms of W/λ as a function of log X. Then, as long as v is constant, the forty-five-degree and the Doppler portions of the curve of growth will be identical for all wave-lengths. All lines having the same value of

Γ/ν will fall on the same damping curve. Where, in Figure 10, each value of Γ corresponded to a different damping portion, in the newer representation the damping curves are distinguished by the values of Γ/ν.

The theoretical curve of growth may be represented as a function of the two parameters, X and Z, where X is given by (4) and where

$$Z = (\Gamma/\nu)(c/v). \tag{18}$$

Then we may write

$$(W/\lambda)(c/v) = F(X, Z) \tag{19}$$

where F is the function representing the curve.

A graph of the curve of growth, thus defined for various values of Z, is given in Figure 11. In the analysis of stellar spectra the parameter v

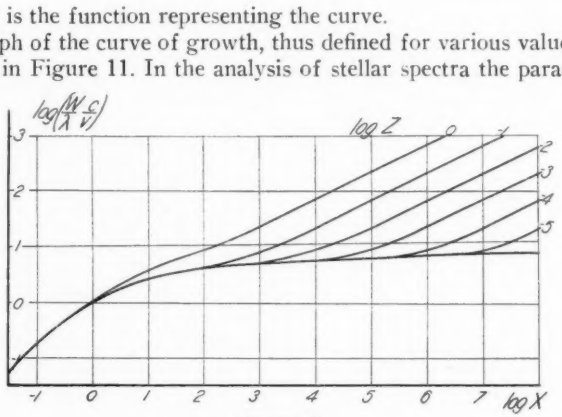


FIGURE 11

cannot be fixed from *a priori* conditions. Instead of plotting the curve of growth as in Figure 11, we are forced to plot $\log W/\lambda$ as a function of $\log X'$, where X' is the theoretical line strength. $\log X'$ differs from $\log X$ by only an additive constant, as yet undetermined. By superposing the observational curve of growth upon the theoretical, Figure 11, sliding the scales both horizontally and vertically until the best fit is obtained, we may determine directly the values of c/v, of Z, and of the constant

$$Y = \log X/X'. \tag{20}$$

The optical depth at the line center, X, can be written, with the aid of certain wave-mechanical results, in a very simple form. We have referred to the theoretical f-values. As we mentioned in §(1), the absolute f-values are difficult to compute. The relative f's for various spectroscopically related lines, like the D-lines of sodium, may be predicted.

Various astronomers have privately expressed an uncertainty as to the proper way of approaching the analysis of stellar spectra with the aid of multiplet data. A brief outline of the atomic theory involved may not be out of place. It is well known that spectral lines may be classified according to multiplets. Multiplets, in turn, may be classified according

to the electron transition producing them. Electrons in an atom are designated by the total quantum number n, and the azimuthal quantum number l. The numerical values of the latter are usually indicated by a literal substitute for the numerical value:

s, p, d, f, g, h, ... etc., for
0, 1, 2, 3, 4, 5, ... etc., respectively.

Thus, instead of writing nl, we may refer to the electrons variously as 1s, 2s, 2p, 3d, etc. The number of electrons of given variety is indicated as an exponent.

A specification of all the electrons in an atom is called a configuration. The rule regarding permitted transitions between two configurations of electrons is that the l of the "jumping" electron change by ± 1. A relatively simple example of such a transition is

$$(1s^2\,2s^2\,2p)\;3p \rightarrow (1s^2\,2s^2\,2p)\;3d$$

of O III. The portion of the configuration that does not change, *i.e.*, the "parent" configuration, has been enclosed in parentheses.

The number of lines occurring as a result of the transition depends on the nature of the atom. When the coupling between the electrons is of the "LS" variety, there arise, for the transition under consideration, twelve multiplets and forty lines, the intensities of the intercombination lines being zero. A tabulation of all the lines (or multiplets), occurring in a transition between two configurations, whatever the coupling, is called a "transition array," sometimes erroneously referred to as a "super multiplet." The strengths, S, of the individual multiplets of the array, as calculated from wave-mechanics, are tabulated in Figure 12.

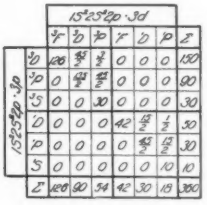


FIGURE 12

MULTIPLET STRENGTHS IN A TRANSITION ARRAY (LS COUPLING).

The values are taken from the tables computed by Goldberg.[1] Let s be the strength of any multiplet line, as given for example in the tables of White[2] and Russell,[3] and let Σs be the strength of all the lines of a multiplet. Then the individual strength of a line may be written as $Ss/\Sigma s$.

[1] *Ap.J.*, **82**, 1, 1935. *Cf. ibid.*, **84**, 11, 1936, for the factors to reduce tabulated strengths to absolute scale.

[2] White and Eliason, *Phys. Rev.*, **44**, 753, 1933.

[3] Russell, *P.N.A.S.*, **11**, 314, 1925.

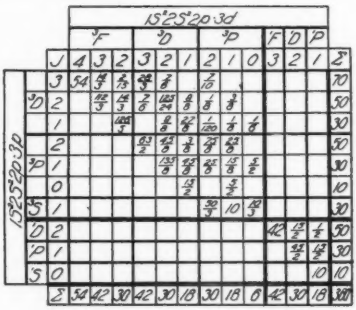


FIGURE 13

LINE STRENGTHS IN A TRANSITION ARRAY (LS COUPLING).
$X' = Ss/\Sigma s$

These values, tabulated for the array in question, are given in Figure 13.

Note that the sums of each row and column, *i.e.*, for each J-level, are proportional to $2J + 1$, the statistical weight of the level. Further, the summations for each term are proportional to $(2S + 1)\ (2L + 1)$, the weight of the term. Finally, the total strength of the entire array is

$$\Sigma S = 2\tilde{\omega}_k\, l\,(4l^2 - 1), \tag{21}$$

where l is the *larger* of the initial or final l-value of the jumping electron and where $\tilde{\omega}_k$ is the total weight of the parent configuration. For the array considered, $l = 2$, $\tilde{\omega}_k = 6$ (the weight of the ion term $1s^2\ 2s^2\ 2p\ {}^2P$), and

$$\Sigma S = 360,$$

in accord with the tabulated result. In passing, we note that the relative strengths within the multiplet ${}^3P$ - ${}^3D$ are the same as for either of the two "super-multiplets" given in Figure 12.

The array here considered is of relatively simple character. For more complicated arrays, particularly those for which the jumping electron is equivalent to others in either the initial or final configuration, Menzel and Goldberg* have indicated the proper procedure. For complex atoms the approximations of LS coupling may fail to hold. When the inter-system or interparent combinations, "forbidden" by the rules of LS coupling, begin to appear with any considerable intensity, the simple line strengths should be used with caution. As the zero (or vacant squares) of a transition array are filled in with non-zero values, the sum rule for the entire array will often remain unaffected. As an intersystem line increases, the permitted lines in the same row and column diminish in strength. In some cases, when two configurations interact, the sum-rules will hold only for the super-array consisting of both transitions.

Ap. J.*, **84, 1, 1936.

We now proceed, without formal proof, to the final mathematical formulation of the theory. Let ρ denote the wave-mechanical integral,

$$\rho = \left[\int_0^\infty r\, R(n,l)\, R(n',l-1)\, dr\right]^2 \tag{22}$$

the square of the first-order electric moment, expressed in atomic units. Then, one can show that X becomes:

$$X = [N_a/b(T)]e^{-\chi_{J'}/kT}\,(1/3\sqrt{\pi}R)\,(\pi e^2/mc)\,(c/v)\,(\rho/\sqrt{4l^2-1})\,(Ss/\Sigma s)$$
$$= 1.51\times 10^{-15}\,[N_a/b(T)]\,(c/v)\,(\rho/\sqrt{4l^2-1})\,(Ss/\Sigma s)\,e^{-\chi_{J'}/kT} \tag{23}$$

where use has been made of the Boltzmann formula, 1.8, $\chi_{J'}$ being the excitation potential of the lower level involved in the production of the given spectral line. $\chi_{J'}$ is measured upward from the ground level as zero. N_a is the total number of atoms of the element in the particular ionization stage under consideration. R is the Rydberg constant, in frequency units. ρ, being a function of only n, n', and l, is constant for any given array.

We now set, for a given line,

$$\log X' = \log S - \log \Sigma s/s, \tag{24}$$

Tables of $\log \Sigma s/s$ have been given by Russell.* Then, by (20),

$$Y = \log(X/X') = -17.82 + \log[N_a/b(T)] + \log(c/v)$$
$$+ \log(\rho/\sqrt{4l^2-1}) - (5040\,\chi_{J'}/T) = L - (5040\,\chi_{J'}/T).$$

The procedure for determining the temperature of the solar or a stellar atmosphere may now be outlined. Suppose that a fair number of lines of a given transition array have been measured for equivalent widths and suppose that a table of line strengths is available, as in Figure 13. For each multiplet we plot $\log W/\lambda$ against $\log X$, and, superposing this diagram on Figure 11, read off the difference $\log c/v$, when the best fit has been obtained. The average of all the values of $\log c/v$ may then be taken, and the vertical scale of the curve adjusted to read $\log W/\lambda$ instead of $\log (W/\lambda)\,(c/v)$. For each measured W/λ, the value of $\log X$ may be read directly from the curve of growth. Since $\log X'$ is supposed known, we may compute Y for each line of the array.

Theoretically, the Y's for various lines of the array differ only in the last term of (24). Hence, if Y, as ordinate, is plotted as a function of the excitation potential $\chi_{J'}$, as abscissa, the resultant points should define a straight line with negative slope $5040/T$. The temperature of the atmosphere may thus be inferred.

An example of such a plot for the array $3d^34s - 3d^34p$ of Ti I, is shown in Figure 14. Each point is the mean Y for an entire multiplet. The slope of the line corresponds to a temperature of 4450°. 165 lines were used in the analysis. Some of the scatter, particularly the marked discrepancy for the points at $\chi_{J'} = 1.4$, is due to departure of Ti I from

*Ap. J., **83**, 129, 1936.

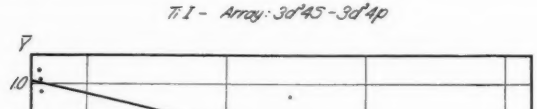


FIGURE 14

LS coupling. Apparently only a relatively small fraction is to be ascribed to failure of the Boltzmann law to hold for the assembly.

The order of magnitude of the low excitation temperature has been confirmed by data from other transition arrays. Substantially identical temperatures are obtained when laboratory-determined strengths are used in place of the theoretical.

We now turn to the stellar, as distinguished from the solar, problem. The observational data for stars are, for obvious reasons, less extensive and less accurate than those for the sun. Curves of growth, in consequence, are often difficult to determine.

The chief factor that distinguishes stellar from solar curves of growth is the value of $\log c/v$. For the sun, the velocity determined is in accord with the gas-kinetic value defined by (1.7), for the solar temperature and appropriate atomic mass. For stars, however, particularly the giants and super-giants of early spectral type, Struve finds v's so much larger than the gas-kinetic that it is impossible to interpret them as temperature motion.

Struve ascribes the effect to turbulence in the stellar atmospheres. A re-analysis of Struve's and Williams' observational data has been carried out by Goldberg at Harvard, who employed values of X' derived from solar observation as well as from transition arrays, in deriving curves of growth. The results of Goldberg's analysis will soon be published and I shall not attempt a detailed review here. Struve* has referred to an unpublished and unsuccessful attempt by myself to reconstruct his curves of growth independently. The curves of growth derived by Goldberg confirm my conclusions; for many of the stars, the curves differ markedly from those of Struve. The turbulence effect discovered by Struve nevertheless persists.

It would not be surprising to find turbulence in the hot super-giants and turbulence may well be the source of the observed distortion of the curves of growth. Although I was an early proponent of turbulence as

*P. A., **46**, 431, 1938. *Cf.* III.

a universal characteristic of stellar atmospheres,[1] and expressed the view that at least the positions of absorption lines might be affected, I still regard the case as "not proved."

The theoretical form of the curve of growth was derived on the basis of very simple postulates. Certain features of stellar spectra, such as the finite central intensities of spectral lines and the tendency of certain lines of a series to appear in emission while the higher series members remain in absorption, suggest that emission and absorption are more nearly balanced than the simple theory supposes. The curve of growth for a star with an extended envelope may possibly be the difference between a purely absorption curve, as in Figure 11, and a curve of somewhat similar form representative of chromospheric emission.

The curves obtained by subtracting two properly chosen growth curves are not dissimilar to those found by Struve and Goldberg. They may exhibit not only the phenomena ascribed to turbulence but also an analogous phenomenon that might be described as "negative turbulence." As a matter of fact several of Struve's curves indicate a velocity *less* than the theoretical gas-kinetic value. It seems quite as reasonable to interpret the discrepancies in terms of modified curves of growth as in terms of turbulence. Observations of equivalent widths over a wide range of wave-lengths, to determine whether or not they exhibit the Doppler effect, will make it possible to decide between the two points of view.

(To be continued)

[1] *Publications American Astron. Soc.*, **6**, 370, 1930.

Sir William Herschel*
1738-1822

By FREDERICK E. BRASCH

[*As is implied in the title, the bicentennial of the birth of Sir William Herschel occurred last year. Although it is a bit late, we feel justified in publishing this paper at this time, in commemoration of that event which was of such great significance to astronomy.*—EDITOR.]

In the life of Sir William Herschel, the art of music and the science of astronomy blend into one of the most beautiful and romantic stories of human achievement. No figure in the history of science can compare with him in versatility of accomplishment. He was born a musician and died an astronomer.

*Paper read before the Rittenhouse Astronomical Society of Philadelphia on November 11, 1938, at a symposium commemorating the bicentenary of the birth of Sir William Herschel.

Astronomy seems to have no particular point of origin in the souls of men. That science is born of the arts from the spirit of other accomplishments. In Copernicus, theology gave birth to the true order of the solar system; Kepler likewise studied for the church, and if he had continued doing so, when would we have found the three great dynamic principles of Copernicus' system? Galileo studied medicine, but discovered the laws of falling bodies after turning to astronomy. Newton was not content to study mathematics for the sake of pure reason, but to prove that Copernicus, Kepler, and Galileo were right, that the law of gravitation was the force that necessarily governs motion, direction, and speed of bodies in the solar system. Herschel left music behind, and turned to astronomy, finding a new planet, eight hundred nebulae, and the infra-red ray.

Sir William was born on November 15, 1738, at Hanover, Germany, the second son of a musically talented father who played the oboe in the band of the Royal Hanoverian Guards.

Possessing the common trait of many accomplished artists, the family was poor, and, in conjunction with this low economic status, the mother had a dislike of learning and lack of interest in the intellectual ambition of her children. The children, Jacob, William, Alexander, Dietrich, and Carolyn, inherited a love of music from their father, and became eminent musicians. The second son, William, seems to have displayed a talent for music which went far beyond that of his brothers and sisters, and, at the age of fourteen, displayed proficiency on the hautboy and violin. His father was then band master of the Guards, and, recognizing his son's ability, concluded that music was his manifest destiny. Due to the straitened economic life of the family, young William found it necessary to support himself, and entered the Guard band as oboist in 1753. The elder Herschel was a great admirer of astronomy, and often on clear nights would point out to the children the beautiful constellations, the position of the planets, and occasionally a comet. In describing the positions of the planets and comets and their orbits, the names of Kepler, Galileo, Newton, and Euler became household words and this often meant discussions late into the night. Probably it was this fact that caused the mother's dislike for learning; it kept the children from their proper rest. In spite of his economic circumstances and chronic ill health, William's father gave to his family an education not often obtained under such trying conditions, a love of beauty in music and in nature.

Toward the end of 1755, stormy times overwhelmed the continent of Europe, and the Seven Years' War was in progress. The peace of England was threatened with an invasion by French troops, and the Herschel family was separated when the father and two sons, William and Alexander, were drafted to England with the Hanoverian Guards. The life of a musician in the Royal Guards proved too hard for both father and son, and after two years' service, young William arrived home, a sick

and penniless deserter. His continued ill health influenced the family to effect his release from military service, and he returned to England within a year. It was only in recognition of his ability as a musician that the matter of penalties was never pressed.

One of the outstanding episodes in William's early life was his first interview with King George III in 1782, when he was publicly handed the King's pardon for the offense of desertion. Two facts may have had their influence in this episode, George III's descent from the royal Hanoverian family and his great love of music.

This military migration proved for England and William Herschel a momentous episode in the history of music and science. With the exception of one or two short visits to Germany, Herschel remained in England for the rest of his life, doubtless out of gratitude to the King. For thirty years he was the outstanding figure in English musical life, and for thirty years more he was England's greatest astronomer.

Young Herschel scarcely could have realized the musical success which lay before him when the Earl of Doncaster engaged him to instruct the band of the Durham militia. His next benefactor was a Dr. Miller, who, after hearing him play, invited Herschel to live with him in Doncaster. There he was free for engagements and the teaching of music. Our musical genius had learned to play the oboe, the violin, and the organ. His next advance was in April, 1764, when he secured the post of organist at Halifax Parish Church, where a new organ had just been installed. His remarkable success with this instrument proved his exceptional ability and the thoroughness of his musical training. His mild manner and even temperament, displayed alike to pupils, friends, and audiences, brought him wide and enviable recognition. However, Herschel did not remain long at Halifax. In 1766 he became the organist of the Octagon chapel at Bath, one of the proprietary chapels of the Church of England. Life in Bath became a continuous round of concerts and music lessons.

In 1772, Herschel's lonely life and his great love for his younger sister, Carolyn, prompted him to invite her to join him. She accepted his invitation, and arrived in August of that year. The second period of Herschel's romantic career began with the arrival of his sister, who proved a devoted and invaluable colleague, acting as housekeeper, singing at his concerts and in the Octagon choir, copying music and later assisting in that pursuit which was to make the name of Herschel famous. For in the midst of the exacting demands and duties of an accomplished and successful musician, Herschel's greatest enthusiasm lay in the direction of astronomical and mathematical study, an inspiration for which his father was responsible. Kindred exactness in the two studies, mathematics and music, appealed to his sense of mental precision. It was by reason of this similarity that his love of music was linked with that of mathematics, while studying the subject in connection with the laws of harmony. Nothing diverted him from his purpose

of self-improvement. Music was not everything to William Herschel, yet he cultivated it with ardour and composed with facility in the style of the contemporary Italian music, that which most nearly approached his ideal.

In Bath he became more engrossed in the study of science in spite of his growing reputation in the music world. He had at his bedside MacLaurin's treatise on fluxions (known today as differential calculus), Smith's Optics, and Ferguson's Astronomy, all well-known textbooks of the period. In addition to books, instruments were soon found in his study. He hired a small reflector to view the heavens, but this mirror soon proved too small for his growing knowledge of the celestial objects, and thus was born his great resolution to make instruments according to his own optical experiences. His bedroom and dining room, as well as the rooms of his brother and sister were all pressed into service as shops and experimental laboratories. His family was kept busy grinding reflectors and other optical parts. Music, mathematics, physics, and astronomy, all played a part in the labors of these ardent students day and night. Music of Bach, Beethoven, and Mozart vied with Pythagoras' divine harmonies. In all three, enthusiasm prevailed in the new field of endeavor, and it soon became apparent that astronomy had found a genius in William Herschel. The loyalty of the sister to her brother, William, was the guiding influence of his greatness. She was his principal aid in research, recording and carrying on independent observations under his direction, and caring for his personal comfort. His brother, Alexander, however, later went his own way, following the career of a concert player.

During the summer of 1774 Herschel began systematic observations in the study of planetary surfaces, together with the theory of errors of observations in planetary movements. Newton's discovery profoundly modified the aims of astronomers, and the question as to whether or not the planets moved in perfect accordance with the law of gravitation was the problem of the time. Refined observations and data of deviation of the motion of the moon and planets in their orbit were of absolute importance before improved theories could be reached by the labors of Laplace, D'Alembert, and Lagrange, contemporaries of Herschel. Two fundamental conclusions were reached, one, that Newtonian law is universally valid, and two, that the solar system is a stable structure.

Along with the work of making and reducing long series of observations, Herschel and his helpers were busy grinding and polishing larger and larger reflectors. Twenty-four hours a day was not sufficient time for this work, and meals were of secondary importance.

The long series of his communications to the Royal Society of London began May 11, 1780, with a discussion of his observations on the famous variable star Mira Ceti, discovered by Fabricius in 1596. This long-period variable has recently been proven to be a double star. Herschel was known to make accurate observations and deductions and to

formulate theories as to why certain celestial phenomena revealed physical and chemical characteristics. An astronomer possessing a mind of flexibility of range is sure to make discoveries quite often beyond his fondest dreams. In Herschel's period, new planets had not yet begun to be found by the dozen. Five, besides the earth, had been known from remote antiquity, and no more seemed to have a proscriptive right to exist. The boundaries of the solar system were of immemorial establishment. Herschel began in 1780 his second review of the heavens, using his seven-foot Newtonian of 6¼ inches aperture. This instrument proved to be his best thus far made, and, with his keen eye, he discovered an "unusual" comet on March 13, 1781. His discovery was modestly reported to the Royal Society under the simple title "An Account of a Comet in the Constellation Gemini." However, the character of its motion, and lack of a fiery tail did not allow his practical mind to accept the notion that it was a comet. Upon further observation and study of this object, the planetary status was established. A new planet had been discovered! This he named in honor of his Royal patron, George III, but contemporary astronomers on the continent attempted to name it Herschel. In the end, however, the name Uranus was proposed by a German astronomer, and accepted by the scientific world.

This great discovery was the turning point of Herschel's career. It transformed him from a music loving amateur astronomer to the status of a professional astronomer. In November, 1781, he journeyed from Bath to London to receive in person the Copley Medal awarded by the Royal Society, and a few days later was elected a Fellow. Shortly afterward he received the appointment of Royal Astronomer with the modest salary of £200 a year. Sir William was now the King's astronomer, with all possible freedom to carry on research to his great contentment and peace of mind. This position as astronomer to the Court of George III must not be confused with that of Astronomer Royal at Greenwich.

With his new position near Windsor, the King's summer palace, further discoveries of great importance to the history of astronomy were made. He continued to make better and larger reflectors until they reached the size of the great 40-foot, which was approximately 50 inches in diameter. The excitement of its introduction to the world of science is comparable to both the feeling of amazement when the 100-inch reflector of the Mt. Wilson Observatory was turned upon the heavens, and the attention which is concentrated on the impending completion of the 200-inch reflector. When one realizes the difference between the mechanical operations of telescopes of Herschel's time and those of today, it is a great wonder that he made so many excellent observations and epochal discoveries.

The King's astronomer, now fully equipped with the most powerful telescope of the day, became the great explorer of the heavens. His method of exploring was called "sweeps," than which a more comprehensive and unique term could never have been coined.

Discoveries followed one after the other, and any single one would have assured him a lasting reputation. Having already added one new planet to the solar system, he discovered in 1787 with the 20-foot telescope that Uranus had two satellites. This was followed two years later with the discovery of the sixth and seventh satellites of Saturn with the 40-foot reflector. Each discovery meant more work, there were observations to be copied and papers to be written. Members of the Royal Society sought his presence at discussion meetings, and finally his reputation attracted famous astronomers from the continent. In the beginning of his career, he was surrounded by royalty and society; now his life was one of scientific glory. As he steadily advanced, he carried with him his devoted and untiring sister, Carolyn, without whom his life work would have lagged, for it was she who inspired him and fed him when his hands could not be taken from the polishing process of the new mirror. To his last days, Carolyn completely sacrificed herself, and her powers of endurance carried her life twenty-five years beyond his.

Newton said that, if he had seen farther than most others, it was due to the fact that he stood on the shoulders of giants. Herschel, the Newton of his age, modestly said to his friends, "I have looked farther into space than ever a human being did before me; I have observed stars whose light must take two millions of years to reach this earth. I really felt for the moment as if I were conversing with a supernatural intelligence."

Herschel was the founder of sidereal astronomy, and examples of his extensive astronomical observations and experiments are found in the following variety of problems:

I. Planetary motion and surface markings, including the mountains of the moon.
II. Double star measurements (a type of work of which he was the originator).
III. Structure of the nebulae and star clusters.
IV. Comets and satellites of planets.
V. Comparative brightness of fixed stars.
VI. Variable stars.
VII. Invisible rays of the sun.
VIII. Direction and velocity of the motion of the sun and solar system.
IX. Colored and concentric rings, known as the Newton rings.

In 1912 there were collected and edited under the direction of a joint committee of the Royal Society of London and Royal Astronomical Society the scientific papers of Sir William Herschel. They include early papers hitherto unpublished, and are introduced by a biographical sketch compiled mainly from unpublished material by the late Dr. J. L. E.

Dreyer, the distinguished historian of astronomy. These papers are published in two large royal quarto volumes, 597 pages and 718 pages, respectively, and represent a splendid memorial to the life and work of England's famous musician and astronomer.

Sir William's marriage in 1788 was a great blow to Carolyn, but the wound gradually healed. The birth of a son, John, completed the reconciliation which had been partially brought about by her love for her brother and the friendliness of her sister-in-law.

Many honors were bestowed upon Herschel, both in music and astronomy. Besides being a Fellow of the Royal Society, he received the degree of honorary LL.D. from Oxford in 1786, and was elected Foreign Associate of the French Institute in 1802. He was one of the great scientists honored by election to our own American Philosophical Society in January, 1785. He was a friend of Benjamin Franklin and Joseph Priestley, and was well known by David Rittenhouse, whose life history is comparable to Herschel's. On April 5, 1816, Herschel was created a Knight of the Royal Hanoverian Guelphic Order. He became the first president of the Royal Astronomical Society in 1821, but his advanced age did not permit him to take an active part as a presiding officer. He showed his interest, nevertheless, by allowing his last paper to appear in the memoirs of that Society.

On the 25th of August, 1822, in his eighty-fourth year, Sir William Herschel died at his home at Slough, and lies buried close by in the churchyard of St. Lawrence at Upton. To those who love to wander in search of recollections of the famous dead, a visit to the venerable Westminster Abbey will disclose a simple memorial to Herschel in the floor close by the resting place of Newton.

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Planet Notes for March, 1939

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The positions of the sun for March 1 and March 31, respectively, are: $\alpha = 22^h\,44^m.3$, $\delta = -8°\,0'.3$; $\alpha = 0^h\,34^m.5$, $\delta = +3°\,43'.3$. The sun is in the constellation Aquarius until March 14, when it enters Pisces. It will then be in Pisces for the remainder of the month. According to the constellation boundaries adopted by the International Astronomical Union, as employed in the new edition of *Norton's Star Atlas*, the southern limb of the sun will be in the constellation Cetus on March 28. Spring begins on March 21, $12^h\,29^m$ (6:29 A.M., C.S.T.), when the center of the sun's disk crosses the equator.

Values for the equation of time are as follows:

Date 1939	Equation of Time (Mean - Apparent) m s	Date 1939	Equation of Time (Mean - Apparent) m s
Feb. 28	+12 53	Mar. 16	+ 9 6
Mar. 4	+12 7	20	+ 7 57
8	+11 12	24	+ 6 45
12	+10 11	28	+ 5 32
		April 1	+ 4 19

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	March 5	18	0
Last Quarter	12	21	37
New Moon	21	1	49
First Quarter	28	12	16
Perigee	4	11	
Apogee	16	15	

Mercury. The most favorable opportunity of the year for northern observers to view Mercury as an evening star will occur on March 17, at the time of greatest eastern elongation (18° 27′). The stellar magnitude at the time of greatest elongation (March 17, 1^h) will be 0.0, and the position of the planet, $\alpha = 0^h\ 47^m.6$, $\delta = +7°\ 27'.5$. For a few days before and after March 17, the planet will be a conspicuous naked eye object in the evening sky, and well placed for telescopic observation by amateurs.

Venus. Venus is still a conspicuous morning star in the southeastern sky, but is gradually diminishing in brightness, changing from magnitude —3.8 to —3.6 during the month. During the corresponding period the distance from the earth increases from 83,280,000 miles to 104,020,000 miles.

Mars. Mars is a morning star, and will be in western quadrature with the sun March 21, 19^h. It moves from Ophiuchus into Sagittarius on March 13. The magnitude of the planet will be +1.0 on March 1, and the brightness will increase by almost 60% during the month.

Jupiter. Jupiter will be in conjunction with the sun on March 6. A note by Dr. Seth B. Nicholson on p. 50 of the December, 1938, issue of *Publications of the Astronomical Society of the Pacific,* announces that the photographic magnitudes of Jovian satellites X and XI, recently discovered by him, have been determined as 18.8 and 18.6, respectively. These are the photographic magnitudes the satellites would have at the time of opposition with the sun, or at a distance of 4.2 astronomical units from the earth. The magnitudes were determined from photographs of 20 minutes exposure, taken with the 100-inch Hooker telescope. With these data, and on the assumption of a color index of 1.0 and an albedo similar to that of other satellites, the diameters are found to be, for X and XI, respectively, 17.5 and 15.5 miles. Similar computation gives 19.5 miles for the diameter of Jupiter IX (photogr. magn. 18.6).

Saturn. March 1 finds Saturn an evening star, 4° north of the celestial equator and 2^h east of the sun. The elongation from the sun is rapidly diminishing, however, and by the end of the month the planet will probably be too close to the sun for observation. Conjunction with the sun will occur April 11.

Uranus. Uranus is an evening object, about a degree northeast of the 5.5 magnitude star, σ Arietis. The positions of the planet for March 1 and March 31, respectively, are: $\alpha = 2^h\ 48^m.3$, $\delta = +15°\ 50'.9$; and $\alpha = 2^h\ 53^m.2$, $\delta = +16°\ 13'.1$. The planet's angular diameter will be 3″.4 during March, and its stellar magnitude,

6.0. An occultation of Uranus by the moon, invisible in the United States, will occur March 24, the time of conjunction in right ascension being $16^h\,24^m$, G.C.T.

Neptune. Neptune reaches opposition with the sun on March 13. A finding chart for Neptune appears in the January issue of POPULAR ASTRONOMY, under "Planetary Phenomena in 1939." On March 10, 10^h7, Neptune passes 1′ 14″ from the 9.0 magnitude star, B.D.+4°2498, and on March 25, 0^h0, it passes 2′ 20″ from the 9.0 magnitude star, B.D. +4°2496.

Asteroid Notes

By HUGH S. RICE

A close examination of official asteroid data of the Astronomisches Rechen-Institut of Berlin-Dahlen, Germany, discloses the usual progress made by this institution. At the present time there are 1453 asteroids with well-known elements; this is an increase of 36 over the number of planets known one year ago. Besides the 1453, there are three having exceptional orbits—Apollo, Adonis, and Hermes—whose elements are also given. These three, together with Amor, are the planets of closest approach to the earth. Their magnitudes range from 17 to 19. All but a very few of the first 1350 asteroids have names. The last hundred are partly named, and partly still with only the provisional designation, as 1938 ED_1, which is the temporary name for number 1453. The new planets added are naturally of faint magnitude, as the bright ones have likely all been discovered before this. The brightest asteroids whose elements were added this last year, are of magnitude 13.4, and the faintest one, $16^M.5$ (except the unusual group including Hermes and others).

The Rechen-Institut has been issuing its bulletins as usual, containing observations (both approximate and precise) and ephemerides, also miscellaneous announcements. In December they tabulated the observations made from November 9, 1937, to November 9, 1938, to show the distribution of observations at each station. From this we can see the relative amount of observing work on asteroids that was done at each of the observatories engaged in this important research. We are giving the table herewith, adding the names of the countries, and grouping the approximate and precise observations together, for our purpose.

Location	Observations	Location	Observations
Algiers, Algeria	303	La Plata, Argentina	60
Barcelona, Spain	100	Nice, France	324
Belgrade, Yugoslavia	167	Rutherford, U. S. A.	8
Bergedorf, Germany	408	Simeis, Russia	241
Bordeaux, France	71	Sonneberg, Germany	44
Budapest, Hungary	140	Torino, Italy	52
Bukharest, Romania	147	Turku, Finland	350
Cordoba, Argentina	3	Uccle, Belgium	312
Heidelberg, Germany	178	Wiesbaden, Germany	4
Innsbruck, Germany	1	Yerkes, U. S. A.	52
Johannesburg, South Africa	292	Zô-Sè, China	38

From the tabulation it will be found that 3295 asteroid observations were made within the year. The greatest number of precise observations (60) was made by La Plata. The greatest total number of observations was made at Bergedorf. We notice that Germany has five important observatories specializing in asteroid work, while France, Argentina, and the United States each has two. For the two in our country, Professor Van Biesbroeck furnishes the astro-photographic data at Yerkes, with the 24-inch reflector; while Meyer at Rutherford makes his plates with a 12-inch instrument.

As to minor planets observable with a small telescope, it happens there are none coming to opposition during February and early March, that are brighter than magnitude 10, except 82 Alkmene. The next brightest one is 349 Dembowska. We give below the ephemerides as computed by the Rechen-Institut. Both of the planets are in central Leo.

Observers now have their last opportunities (of this apparition) to see Ceres. On February 9 it is about 8½° northeast of μ Ceti, from which it travels to a position about 5° south of the Pleiades on March 17. The magnitude averages 8.4 during the period. Later, it comes to conjunction with the sun, and its ephemeris for the next appearance starts with November. Pallas, Juno, and Vesta are not in good location for observation until later in the year.

Observers doing extensive work on asteroids of magnitudes below 10 should have the complete lists of ephemerides as published by the Astronomisches Rechen-Institut, which we import from them.

EPHEMERIDES OF ASTEROIDS. FOR 0^h U.T. EQUINOX OF 1950.

82 ALKMENE ($9^M.8$)

		α h m	δ ° ′
Feb.	2	10 49.5	+12 6
	10	10 44.4	12 36
	18	10 38.1	13 9
	26	10 31.3	13 40
Mar.	6	10 24.5	14 6
	14	10 18.5	+14 24

349 DEMBOWSKA ($10^M.2$)

		α h m	δ ° ′
Feb.	10	11 22.1	+14 41
	18	11 16.6	15 17
	26	11 10.2	15 53
Mar.	6	11 3.4	16 24
	14	10 56.6	16 49
	22	10 50.3	+17 5

Hayden Planetarium, American Museum of Natural History,
New York City, January 11, 1939.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.

Date 1939	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION *a* m	IMMERSION *b* m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION *a* m	EMERSION *b* m	EMERSION Angle E from N °
Mar. 2	68 Gem	5.1	7 1.1	+0.7	—3.4	169	7 25.7	—0.7	+0.3	223
4	ω Leo	5.5	3 56.2	—1.6	—0.9	111	5 9.2	—1.3	—1.5	300
10	26 Lib	6.3	9 31.0	—2.2	+0.3	66	10 39.3	—1.7	—2.0	319
11	56 B.Sco	5.1	7 34.3	—0.6	—1.4	156	8 24.0	—2.6	+2.0	231
11	β^1 Sco	2.9	7 35.0	—0.5	—1.5	158	8 22.9	—2.6	+2.1	230
12	109 B.Oph	6.2	10 59.4	—2.0	+0.2	70	12 23.0	—2.0	—1.3	289
14	89 G.Sgr	6.5	7 32.9	—0.9	+2.1	67	8 40.7	—0.9	+0.7	292
30	BD+14°1850	6.4	6 1.1	—0.3	—1.0	77	6 47.5	+0.3	—1.9	318
30	60 Cnc	5.7	22 1.1	—1.2	+1.5	83	23 6.3	—1.3	—0.8	312

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.

Mar.	4	ω Leo	5.5	3	30.8	−1.4	−1.4	139	4	40.0	−2.1	+0.1	269
	8	α Vir	1.2	9	26.4	−2.6	+0.8	58	10	13.4	−1.0	−3.0	346
	10	26 Lib	6.3	8	48.5	−2.1	+0.6	90	10	10.0	−1.8	−0.9	305
	10	28 Lib	6.2	12	59.0	−1.4	−1.2	97	14	13.0	−1.0	−1.5	276
	12	109 B.Oph	6.2	10	17.4	−2.1	+1.0	81	11	45.9	−2.2	−0.4	288
	13	16 G.Sgr	6.5	12	14.9	−2.3	+0.2	89	13	47.6	−2.1	−0.3	260
	14	BD+19°5182	6.4	11	15.9	−2.0	+1.7	65	12	43.1	−2.2	0.0	282
	28	19 B.Gem	6.2	5	14.0	−0.4	−0.9	78	6	5.8	+0.3	−1.8	302
	28	110 B.Gem	6.2	23	42.2	−2.2	+2.7	53	0	36.3	−1.6	−3.1	329
	30	BD+14°1850	6.4	5	55.7	−0.6	−1.3	100	6	54.5	−0.1	−1.8	299
	31	κ Cnc	5.1	4	40.5	−2.3	+0.5	60	5	22.4	−0.1	−3.5	348

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.

Mar.	3	84 B.Cnc	6.4	5	18.3	−2.2	+0.3	89	6	30.8	−1.5	−2.0	315
	7	χ Vir	4.8	14	35.7	−0.5	−2.9	160	15	11.7	0.0	−0.1	236
	8	α Vir	1.2	8	20.8	−1.5	0.0	114	9	39.3	−1.7	−0.6	299
	10	26 Lib	6.3	8	12.9	−0.4	−0.4	138	9	16.2	−1.6	+1.3	261
	10	28 Lib	6.2	12	5.4	−2.2	−0.6	112	13	33.7	−2.2	−0.8	276
	11	ν Sco	4.3	10	0.2	−2.4	+2.9	54	10	51.2	−0.7	−1.7	336
	12	109 B.Oph	6.2	9	36.4	−0.5	+0.3	121	10	46.0	−1.5	+1.3	259
	13	16 G.Sgr	6.5	11	19.8	−1.2	+0.5	112	12	39.3	−2.1	+1.3	253
	14	BD−19°5182	6.4	10	33.6	−0.5	+1.2	95	11	46.3	−1.2	+1.3	264
	28	19 B.Gem	6.2	5	1.4	−0.9	−1.9	121	6	5.7	−0.9	−1.0	263
	29	λ Gem	3.6	7	50.0	0.0	−2.1	136	8	39.0	−0.2	−0.8	256
	30	BD+14°1850	6.4	5	38.0	−0.9	−2.6	146	6	38.3	−1.7	−0.6	258
	31	κ Cnc	5.1	3	39.3	−1.9	−0.7	116	5	0.1	−1.9	−1.0	292

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In this paper are given reports on the October, November, and December, 1938, showers, with a belated one on the Perseids. The last two issues of these "Notes" had, respectively, results on the October Orionids and the August Perseids, these later reports probably complete each. It is now possible by considering the three papers together to get a general idea of the richness of the streams involved. I wish first to call general attention to three groups of observers whose results follow in very brief form in the table below, and again to the data of one of our outstanding observers who works in India and is, so far as I know, the first man in his great country to observe with regularity over a period of many years, in such a manner as to make his results valuable. The Honolulu group, under Miss Louise M. Larrabee a teacher in one of the high schools in that city, consisted of 60 students, boys and girls. As a result a splendid set of counts for several nights are reported from a longitude from which data are specially valuable. The number of observers in this group is so large that I have only named those who observed at least one hour, and have taken the hourly averages for the others, combined, for each night in question. Why cannot science teachers in other schools to say nothing of colleges, favorably located, undertake a similar campaign? It is safe to say that to many of these young people who took part it will be something they will remember with pleasure and which may help them to have a juster view of what science attempts to teach.

Next the Louisville Astronomical Society, which has worked for some years, reports through its efficient secretary, Miss Shapinski, a set of counts which will

give an excellent idea of the richness of the Geminids near or at maximum. Then Prof. Donald Faulkner of Stetson University, Florida, writes that he had two groups out for two nights of the Leonid epoch, which were situated about 20 miles apart. Their work was undertaken with a view to determining of heights and they plotted 275 and 269 meteors respectively. Professor Faulkner is going to have them compute heights for those meteors whose identities are proven. It is somewhat of a pity the base line was not two or three times as long, as 20 miles will accentuate the inevitable errors of plotting, especially for relatively untrained observers. The enterprise was, however, an ambitious one and evidently carried out with great care, and much credit is due for such a successful conclusion. Lastly, the splendid series of observations which cover both Orionids and Leonids, from Professor Khan in India, is to be mentioned with great appreciation. His lower southern latitude, and perhaps extra keen eyesight, gave him an advantage he has used well. Thanks to him, and to the series by Loreta in Italy previously published in these "Notes," as well as to our American members, we have data for a good determination of the richness of the 1938 cross-section of the Orionid stream. It will be noted that he saw over 2 meteors per minute on the best nights of both months, indicating what may be expected under good conditions. The number he actually classifies as Orionids were: on October 17, 0; 18, 8; 19, 12; 20, 5; 21, 8; 23, 10±; for the other dates I am not entirely clear as to his method for classifications. As to the Leonids he gives for November 15, 16; November 16, 12. I have taken the numbers for "class" as given by Professor Khan without checking, as his maps were not submitted. He remarks that this is the best Leonid return for the past four years.

Of those who recorded the class in December, three of the group in Joliet, Illinois, give 81 Geminids and 6 sporadic meteors. R. M. Dole records every meteor on December 12 and 13 as a Geminid on his record sheets but plots a few sporadic, without serial numbers, on his maps. Dole also records *nearly all* the meteors he saw on October 16 and 20 as Orionids, which is at variance with the ratio of classification of Professor Khan. I believe, however, he frequently does not record the sporadic meteors, which, if *true* in these cases, would account for the different ratios. The Louisville Astronomical Society had a mean rate for all meteors on December 13 of 30.9 per hour, which is the average rate for 11 observers and should therefore be very accurate indeed. In passing, such groups can do most valuable work *provided,* as in this instance, every one observes absolutely independently of the others, keeping the count of every meteor he sees, no matter if the same one is recorded by everyone else. For the only unit that has meaning in our way of recording and publishing is the rate per observer per hour. This procedure is urged upon our members and has been often explained with the utmost patience, but in vain so far as some are concerned. These have the erroneous conception that if one sees a meteor the other should not count it in his rate. Nothing could be further from the correct practice, for it would take at least 32 observers to see all meteors visible in a hemisphere of the sky, so no matter how large the group, in any reason, they will see only a fraction of the total number visible anyhow. Cannot our members understand this fact and stick to the regular rule?

Finally, it is time that every observation made in 1938, and not yet reported, be sent in so that we can include all in the annual report which should be prepared in the next month. This remark is applicable also to non-members and persons in the A.A.V.S.O. who kindly furnish us with telescopic meteor observations. Also the request is again made that anyone who has the observation of a meteor, whose

train endured a minute or more, no matter what the year it was seen, will please send it to me for use in my paper on that subject.

In the "Remarks" (R.) column, a indicates that the meteors were plotted regularly; b that more or less description is given beyond mere counts, (sometimes a very great deal; c that counts only were submitted; the numbers refer to how many observers took part at the station.

Observer and Station	Oct.	1938 Began	Ended	Min.	F.	Met	Rate	R.
Latake, S., Honolulu, T. H.	19	11:00	14:00	180	1.0	259		2c
Larabee, Miss L. M., reports for 60 students, Honolulu, T. H.:								
Afuso, T., ...	17	12:00	13:00	60		15	15.0	c
Takawana, Miss M.	18	12:00	14:05	125	1.0	38	18.3	c
Average	18						14.9	6c
Yanaguchi, T.	19	11:30	12:30	60	0.8	5	5.0	c
Kuninobu, S.	19	12:00	13:00	60	0.8	26	26.0	c
Nakano, S.	19	12:00	13:00	60	0.8	12	12.0	c
Ng, Miss E.	19	12:10	13:10	60	1.0	28	28.0	c
Young, Miss F.	19	11:00	12:30	90	0.8	20	13.3	c
Average	19						19.3	20c
Newland, Miss M.	20	12:15	13:15	60	1.0	31	31.0	c
Fogitani, M.	20	12:00	13:00	60	1.0	7	7.0	c
Okahata, M.	20	16:45	17:45	60	1.0	20	20.0	c
Kajioka, H.	20	12:00	13:30	90	1.0	32	21.3	c
Average	20						18.5	14c
Souza, Miss F.	21	11:00	12:00	60	1.0	2	2.0	c
Yoon, P.	21	16:00	17:00	60	1.0	3	3.0	c
Suzuki, R.	21	12:00	13:00	60	0.8	2	2.0	c
Dewa, Miss F.	21	15:30	16:30	60	1.0	15	15.0	c
Kaalou, K.	21	11:15	14:00	165	1.0	27	10.0	c
Larrabee, Miss L.	21	14:00	16:40	160	1.0	28	10.5	c
Average	21						31.7	6c
Dole, R. M., Cape Elizabeth, Me. ..	16	12:30	13:30	60	1.0	13	13.0	a
	20	12:30	16:15	225	1.0	89	23.8	a
Leerman, J., Baltimore, Maryland ..	19	13:15	14:15	60		6	6.0	c
Page, T. J., Stamford, Conn.	20	15:40	17:22	102		19	11.2	a
	22	8:07	9:06	59		22	5.6	a
	22	13:20	17:14	234	1.0	22	5.6	a
	26	7:10	10:51	221		12	3.3	a
Erickson, E. A., 23° W, 23° N	27	13:30	15:32	122	0.5	10	4.9	
Khan, Mohd. A. R., Begumpet, India	3	13:30	14:30	60	0.6	10	10.0	b
	16	15:30	16:00	30	0.5	6	12.0	b
	17	12:45	13:30	45	0.6	11	14.7	b
	18	12:45	14:00	75	1.0	27	21.6	b
	19	15:30	16:30	60	1.0	35	35.0	b
	20	17:00	17:30	30	1.0	16	32.0	b
	21	14:00	15:00	60	0.6	37	37.0	b
	23	12:30	14:00	60	0.7	37	37.0	b
	24	15:35	16:47	60		26	26.0	b
	25	16:30	17:00	30	0.9	14	28.0	b
	26	15:05	16:05	60	0.7	33	33.0	b
	29	14:55	15:25	30	1.0	4	8.0	b
Nov.	3	15:25	16:00	35	0.8	10	17.2	b
	15	15:00	17:30	90	0.6	43	28.7	b
	16	14:35	16:05	90	0.7	48	32.0	b
	17	12:00	12:30	30	0.8	8	16.0	b
Dole, R. M., Cape Elizabeth, Me....	14	13:00	15:00	120	0.6	18	9.0	c
	16	13:30	14:30	60	0.7	6	6.0	a
	17	8:15	9:15	60	0.4	18	18.0	c
Olivier, C. P., Upper Darby, Pa. ...	14	15:12	16:17	65	0.5	8	7.4	a
	15	14:10	17:08	170	0.4	31	10.9	a
Alexander, S., Upper Darby, Pa. ..	15	14:20	16:00	100	0.2	20	12.0	c
McArthur, C., N. Quincy, Mass....	14	14:03	15:49	109	0.6	8	4.4	a

Observer and Station	Oct.	1938 Began	Ended	Min.	F.	Met	Rate	R.
Wight, W., N. Quincy, Mass.	14	14:20	15:14	54	0.6	4	4.4	c
Leerman, J., Baltimore, Md.	14	11:00	12:10	70		4	3.4	c
	15	13:10	14:10	60		8	8.0	c
Stone, Wm. R., Santa Barbara, Calif.	15	12:00	15:00	180	0.7	20	6.7	a
	16	12:00	15:00	180	0.9	9	3.0	a
	17	12:30	14:30	120	0.9	5	2.5	a
Glover, C. M., Santa Barbara, Calif.	15	17:+				13+		c
Mastell, R., Hibbing, Minn.	16	10:00	14:00	240	1.0	16	4.0	a
Preucil, F., Joliet, Ill.	16	12:15	13:15	60	0.6	9	9.0	c
Huey, Dr. W. B., Joliet, Ill.	16	12:15	13:15	60	0.6	9	9.0	c
Davis, Philip, Batesburg, S. C.	12	7:30	8:45	75	1.0	12	9.6	c
	13	14:00	15:00	60	0.6	3	3.0	c
	14	13:00	14:00	60	1.0	12	12.0	c
	18	7:40	8:40	60	0.5	2	2.0	c
	23	7:00	8:00	60	1.0	9	9.0	c
*Faulkner, Prof. D., DeLand, Fla..		11:30	dawn		0.7	275		a
Daytona, Fla.		11:30	dawn		0.7	269		a
Page, T. J., Stamford, Conn.	14	7:25	9:05	90		8	5.3	a
	15	11:27	17:15	326	1.0	74	13.6	a
Smith, F. W., Thiells, N. Y.	20	9:30	10:15	45		4	5.3	a
Shapinski, Miss M., Dec.	12	8:00	11:00		1.0	8		4a
Louisville Ky.	13	8:00	10:30		1.0	15		4a
	13	8:00	10:30	90	1.0	41	27.3	c
Shapinski, N.	13	8:00	10:30	120	1.0	68	34.0	c
Landau, J.	13	8:00	10:30	90	1.0	31	20.7	c
Montgomery, K.	13	8:00	10:30	120	1.0	43	21.5	c
Montgomery, E.	13	8:00	9:00	60	1.0	15	15.0	c
Moore, W. L.	13	8:00	10:30	90	1.0	53	35.3	c
Reynolds	13	8:30	11:00	90	1.0	84	56.0	c
Workman, M.	13	8:30	11:00	90	1.0	46	30.7	c
Gaines, Miss J.	13	8:30	11:00	90	1.0	49	32.7	c
Dawson, C.	13	8:30	11:00	60	1.0	37	37.0	c
Gnau, A.	13	8:30	11:00	90	1.0	44	29.3	c
Pirsig, G., Blue Earth, Minn.	11	9:35	10:35	60	0.7	14	14.0	a
	12	9:35	11:35	120	0.8	44	22.0	a
	14	10:10	11:10	60	1.0	9	9.0	a
Dole, R. M., Cape Elizabeth, Me.	12	9:00	11:00	120	1.0	14	7.0	a
	13	9:00	11:30	150	1.0	67	26.8	a
McArthur, C., N. Quincy, Mass.	12	8:55	9:55	60	0.7	14	14.0	a
	12	11:10	12:36	86	0.7	15	10.0	a
	13	9:47	11:19	92	0.9	24	15.7	a
	15	9:47	10:50	93	0.6	5	3.2	a
Jewett, Miss M., Grandview, Tenn.	12	8:00	11:00	120	0.6	19	9.5	c
Smith, F. W., Thiells, N. Y.	11	9:00	10:00	60		3	3.0	a
	12	10:00	11:00	60		8	8.0	a
	13	8:00	9:00	60		2	2.0	a
Avery, V., Banks, N. D.	12	8:50	10:34	104		12	6.9	a
	13	8:30	10:32	122		9	4.4	a
Stone, Wm. R., Santa Barbara, Calif.	11	9:30	12:00	150	0.5	6	2.4	a
	12	10:00	12:30	150	1.0	8	3.2	a
	13	10:00	13:00	180	0.5	14	4.7	a
Leerman, J., Baltimore, Md.	13	12:30	14:30	120	1.0	51	25.5	c
Preucil, F., Jr., Joliet, Ill.	12	10:40	11:40	60		32	32.0	c
Preucil, F., 3rd, Joliet, Ill.	12	10:40	11:40	60		37	37.0	c
Huey, Dr. W., Joliet, Ill.	12	10:40	11:40	60		33	33.0	c
Shaw, E., Joliet, Ill.	12	10:40	11:40	60		22	22.0	c
Bowman, E. F., Kansas City, Mo. Aug.	13	11:10	16:00	290	0.4	45	9.3	ab

*Prof. D. Faulkner, DeLand, Fla., reporting for 2 groups, 2 nights, Leonid epoch.

Flower Observatory, Upper Darby, Pennsylvania, 1939 January 10.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California, Los Angeles

The Oxidation of Meteorites*

By JOHN DAVIS BUDDHUE,
99 South Raymond Avenue, Pasadena, California

Abstract.—The oxide of iron meteorites is typically laminated and magnetic, with a specific gravity of 2.92 to 4.24, and dark brown to black in color. Some occurs as shale-balls, which may result from an abundance of lawrencite. These seem to be a special case of the ordinary rusting of iron masses. Shale-balls resemble certain lava-bombs, but one such mass is known which is non-lamellar and contains traces of Widmanstätten figures. These figures have been seen also in Canyon Diablo, Arizona, oxide. Their preservation may be the result of the oxidation's having begun between the kamacite bands. This type of oxidation is also responsible for the presence of the metallic particles which are found in oxides. A meteorite in an intermediate stage is known. Schreibersite particles are found because of their resistance to oxidation.

Oxides from Willamette, Oregon, and Odessa, Texas, are described and analyses given.

The oxidation of meteorites is accelerated by electrolytic action between the constituents and by the action of lawrencite.

Many oxides bear green stains. In four cases these have been identified as deposits of zaratite. The presence of this mineral and various experiments show that all the nickel need not enter the oxide, and that nickel can be removed by solution. Comparison of nickel contents of oxides and the unaltered metal shows that the oxide contains almost invariably less nickel than the metal. Hence, ancient meteorites may be unrecognizable because they have lost all their nickel.

The mineral composition of the oxides is very imperfectly known. *Rustite* and *ayasite* are suggested as possible names.

As no undoubted preglacial meteorites are known, a study of the oxidation products of meteorites may lead to the identification of ancient meteorites. Nevertheless, it was thirteen years after Pugh's analysis of the rust of the Xiquipilco (Toluca), Mexico, meteorite,[1,2] before Haushofer analyzed the rust of the Cranbourne, Victoria, Australia, iron,[2,3] and after that it was thirty-four years before Cohen described the oxide from the Beaconsfield, Victoria, Australia, meteorite.[4] Since that time, descriptions have appeared slowly, although authors have occasionally recorded that a certain meteorite had a rust coating of a certain thickness, and made unsupported statements regarding its composition. At last, in 1927,

*The revision of a paper read at the Fifth Annual Meeting, Denver, Colorado, June, 1937.

E. V. Shannon made what appears to be the only extensive study of the rusts of meteorites, to date.[5] Several excellent descriptions of the oxides of single meteorites also have appeared, mostly since Shannon's work.

The oxide of meteorites is typically blackish-brown, black, or bluish-black in the interior, although the surface may be light brown. The structure is usually lamellar, a feature not confined, however, to meteorites; and the lamellae are of various thicknesses, though fairly constant for any given meteorite. The specific gravity is very variable. Farrington[2] gives 3.73 for the Canyon Diablo, Arizona, oxide, but I find 2.92; Nininger gives 3.9 for Coldwater, Kansas; Hey gives 4.24 for Henbury, Australia; Gordon gives 4.021 for Hoba West, Southwest Africa; Shepard gives 3.81 to 4.04 for the Canyon City, Trinity County, California, iron rust; and I find 2.17 for Willamette, Oregon; 3.70 for Odessa, Texas; and 4.02 for Monahans, Texas. As a whole, the oxide seems to be always magnetic, but, when powdered, a part of the powder may not be attracted by a magnet. Some of the available analyses apply only to the magnetic part of the powder.

The most frequent occurrence of meteoritic oxide is on the outside of an iron meteorite. The so-called shale-balls seem to be a special case of this. They were first reported from Canyon Diablo, where it was noticed that some masses had only a thin coating of rust, while others had a thick crust measuring several inches, and in some cases the whole mass was rusted. Merrill and Tassin[6] showed that the iron cores of these balls, when present, did not have the typical structure of the ordinary irons, and were especially rich in schreibersite and lawrencite. They attributed the excessive rusting to these differences, especially the abundant lawrencite. Since then shale-balls have been reported from Henbury[7] and from the recently discovered Boxhole Crater,[8] both in Australia. The internal structures of these, however, are not known, except that the only iron core found in a ball from Henbury seemed to be rich in lawrencite. A typical shale-ball resembles a bread-crust lava-bomb. The deep cracks result from the expansion of the lower layers as they are formed. Farrington explains the lamellae as having resulted from the same expansion. He suggests that it causes the rust to become partly detached from the iron, thus providing easy access for air and moisture, so that the process is repeated indefinitely. This process explains also the anastomotic nature of the lamellae, since detachment would not occur always in the same place. Since the oxide has greater volume than the iron, the outer layers must crack open, and eventually the ball disintegrates so that this type of oxide is found usually as flat, or somewhat curved, slabs of various sizes. The Coldwater, Kansas, siderite closely resembles a shale-ball on the outside, but the interior is found to be almost unlaminated. More remarkable still, the Widmanstätten figures are still clearly visible, either as spongy streaks, or as lines of somewhat different color and luster.[9] Similar traces of Widmanstätten figures have been reported by Merrill and Tassin and later by L. F. Brady;[10] and I have found the ataxitic structure of Monahans, Texas, preserved in its oxide.

The composition of the oxides is extremely variable, even in samples from a single meteorite analyzed by the same chemist. Thus, Tassin found FeO = 0.65% and 0.00% in two Canyon Diablo samples, while others reported as much as 3.91%. Attempts have been made to calculate the mineral composition of the oxides from their analyses, but as the figures can be interpreted in more than one way, the results are little better than guesses. New minerals may be present. X-ray methods may help to clear up this point, as nothing is definitely known regarding the mineral composition of the oxides. As the rust is magnetic, magnetite is suggested.

I have here to report two new analyses of the oxides of meteorites. The first is the oxide of the Willamette meteorite. This consists of flat slabs, distinctly lamellar in structure, and blackish-brown to bluish-black in color, except on the outside, which is covered by a light-brown, pulverulent coating mixed with a little soil. This material was discovered by Dr. A. K. Harris at the site from which the Willamette iron was taken.[11] The second material consists of small, rounded, lamellar fragments from the vicinity of the Odessa, Texas, meteorite crater. These are magnetic, dark brown in color, and sometimes whitened with calcium carbonate. They look like miniature shale-balls. The analyses were made by Mr. Patrick of McKean and Patrick, Assayers and Chemists, of Pasadena, California. The iron and nickel were reported as metals but I have recalculated them in what follows as oxides:

	Willamette	Odessa
Fe_2O_3	81.80	77.00
NiO	5.42	5.56
Ignition	8.74	10.20
Loss at 110° C.	1.06	1.63
Undetermined	2.98	5.61
Totals	100.00	100.00
Free metal	0.19	1.03

The free metal represents metallic particles larger than 200 mesh, but the quantities are not very reliable, as the samples were not large.

Nearly everyone who has described Canyon Diablo oxide has reported unaltered schreibersite, and I have seen it myself. Tassin even ascribed the magnetism of the oxide to it. Spencer reported metallic specks that appeared to be schreibersite in the oxide of Henbury, Australia.[7] Shannon found that the oxide of the Cape York, Greenland, meteorite contained 11.4% of unaltered metal. Such particles were reported in the oxide of the Paulding County, Georgia, meteorite,[12] and in that of Cosby's Creek, Tennessee. The Coldwater siderite contained metallic-looking particles, but, according to Nininger, they are not metal. The oxide of the Hoba West iron contains 0.72% of free metal, and C. U. Shepard[13] reported 10% of metallic particles in the oxide of Canyon City, Trinity County, California. I have found flakes of metal in the oxide of Monahans, Texas.

It has been noticed several times that oxidation of meteorites tends to be fastest at the kamacite-taenite interface, and that the oxide may penetrate along these lines for some distance into the iron. The Cookeville, Tennessee, mass seems to represent an extreme result of this process.[14] A continuation of it might result in a mass of oxide's containing occasional particles of residual metal. In fact, the oxide of Cookeville shows just such particles. It seems probable that the metal particles found in the oxides mentioned previously, could have been formed in a manner similar to that which occurred in the case of Cookeville. Schreibersite would be preserved, because it is comparatively resistant to oxidation. Oxidation between the kamacite bands would not result in a lamellar oxide, but it might result in a certain amount of preservation of the structure of the meteorite. It may be that Coldwater once resembled Cookeville, and that Cookeville would have been eventually like Coldwater, if Cookeville had not been found.

It is well known that when two substances with different oxidation-reduction potentials are in contact in an electrolyte, they form a cell, and the more anodic of the pair is oxidized. Kamacite and taenite form such a pair, and so do these two and most of the remaining metallic minerals of meteorites. My experiments show that kamacite is anodic to schreibersite. Moisture forms the electrolyte. This

effect is one of the worst enemies of meteorites. Another enemy is lawrencite. It is hygroscopic and the resulting droplets hydrolyze to form iron hydroxide and molysite. The latter reacts with the free iron to form lawrencite again and the cycle is repeated. Some of the molysite is hydrolyzed to iron hydroxide, lawrencite, and hydrochloric acid. The last, being volatile, escapes, so that the destructive action gradually ceases, unless a new supply of lawrencite is available.

Less is known about the oxidation of stones and stony-irons, except that the expansion of the iron particles into oxide seems to have a disruptive effect, which results in the splitting of some stones into a pile of fragments. Others seem to resist this action and become merely deeply stained with oxide. The metal content may be a deciding factor. Because of their rarity, even less is known about the oxidation of pallasites. H. H. Nininger has described the process in the case of the Brenham Township, Kiowa County, Kansas, pallasite.[15] The "meteorodes," as he calls them, are formed as a result of the rusting of the metallic part and apparently some migration toward the surface to form a laminated, mammillated mass of oxide, inclosing fragments of olivine. The silicate may be partly or wholly altered to sand.

Green stains on the oxides of meteorites have been mentioned by a number of writers, and fully half of the oxides mentioned in this paper show these stains in places. I can find no mention in the literature of any attempt to identify the stains, except in the case of the Winona, Arizona, grahamite. Dr. Heineman identified that stain as zaratite (hydrated nickel carbonate).[16] For this reason, I have tested the green stains of the Canyon Diablo, Xiquipilco, and Monahans oxides, and have found nickel, and probably also carbonate, to be present in all cases. The optical properties, likewise, as far as determined, indicate zaratite. The existence of this mineral shows that all of the nickel does not necessarily enter the oxide, a fact that has been remarked upon by Nininger,[15] who found that the oxide of the Brenham pallasite contained less nickel than the unaltered metal did. In a later paper[17] he showed that this oxide still contains nickel soluble in tap water. I have found the same fact to be true of the Monahans oxide. However, there is a possibility that this nickel is derived from lawrencite. On the other hand, I have shown[18] that a rust stain on a rock from beneath the Willamette oxide contained no nickel, and that the nickel had not been retained in the oxide. The nickel must have been soluble enough, then, to be carried away.

In the following table, I give a comparison of the nickel contents of the metal of certain meteorites, and the nickel contents (calculated as metallic nickel) of the corresponding oxides:

Meteorite	% Ni (metal)	% Ni (oxide)	Diff.	Meteorite	% Ni (metal)	% Ni (oxide)	Diff.
Beaconsfield	7.34	1.32*	—6.02	Henbury	7.40	4.15	—3.25
Brenham Tp.	9.47	2.46	—7.01	"	7.40	4.53	—2.87
Canyon Diablo	7.34	7.69	+0.35	Hoba West	16.50	12.68	—3.82
" "	7.34	6.75	—0.59	" "	16.50	6.98	—9.52
" "	7.34	3.66	—3.68	Odessa	7.25	4.37	—2.88
" "	7.34	5.06	—2.28	Monahans	10.88	5.38	—5.50
Cape York	8.06	5.33	—2.73	Paulding Co.	6.34	5.16	—1.18
				Willamette	8.09	4.27	—3.82

It can be inferred from the analysis of Cookeville that its oxide has lost 5.24% of nickel, and the available information on Augustinovka, Ukraine, may be interpreted to indicate a *gain* of 3.67% of nickel. Oxidation of the troilite of Bella Roca,

*Includes cobalt.

Mexico, resulted in a loss of 2.74% of its nickel. I feel, however, that these last three figures should be accepted with caution. Of the figures in the table, the first two differences for Canyon Diablo are insignificantly small. All the rest show a decrease in the nickel content of the oxide as compared with the unaltered metal. Whether this loss is coincident with oxidation, or continuous after oxidation is complete, is uncertain. The existing data indicate that it is continuous. If so, then, as Nininger has suggested,[15,17] certain ferruginous nodules may be ancient meteorites; moreover, ancient meteorites are not necessarily recognizable by a test for nickel, as all the nickel may be gone.

A name for the rust of meteorites seems desirable. Nininger calls the oxide of his meteorodes *ferrite*, but this name is somewhat ambiguous, since it means also an alteration product of olivine, and meteorodes contain altered olivine. Iron shale or scale and kindred terms are undesirable, because the oxide is not necessarily scaly and is in no way related to shale. *Rustite* and *ayasite* (from the Sanskrit word *ayas* = *iron*) are possible terms. All possible Greek and Latin names seem to have been used for naming other minerals.

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Sound from Ether Waves?*

By H. H. NININGER

Abstract.—The writer is convinced of the reality of sound which is produced, under favorable conditions, by the natural transformation of ether waves into ordinary sound, somewhat as in the radio, and proposes that the adjective *ethaërial* be used to designate such sound. If such sound exist, then the noises which are frequently heard at the same time as a meteor is seen and which have been reported by many observers, may be explained as ethaërial—in contradistinction to true aërial—sounds.

Beginning with my first attempt to locate meteorites in the year 1923, I have been again and again confronted by the claims of witnesses that sounds were heard at the instant of the meteorite's flight. For the most part these witnesses were a hundred miles or more from the line of passage. Obviously, no normal sound, traveling at the rate of 1100 ft./sec., could reach them before the lapse of several

*Read at the Sixth Annual Meeting, Richmond, Virginia, 1938 Dec. 29 and 30.

minutes. For years I regarded these "sounds" as probably subjective and tried to explain them as being due to the association in memory of visual phenomena with sounds which had been experienced as an accompaniment of similar light phenomena in connection with fireworks. However, these reports came so frequently and from so many seemingly credible sources that finally I began to regard the matter as a problem in physics rather than psychology. Literally hundreds of reports have been encountered. Many cases are on record where the informants insist that the sound attracted them from behind or within buildings, and, in some instances of daylight meteors, the sound was commented upon before any light was seen or known about. In two different instances, the witnesses had been previously instructed by me to be on the alert to avoid deception on this point, in the event that they were privileged to see large meteors.

In my paper, "The Great Meteor of March 24, 1933," *P. A.*, **42**, 291-306, 1934, I expressed belief (p. 303) "that there may be, in connection with meteors, ethereal as well as aërial propagation of sound." In 1934, Mr. Elmer R. Weaver of the U. S. Bureau of Standards suggested to me in conversation that possibly ether waves are transformed into sound waves upon striking objects in the environment of the observer. Subsequently, I have consulted some of our leading physicists and have found them divided in their opinion, but the majority were unwilling to admit the possibility of a distant meteorite's being the source of sound heard simultaneously with its passage.

A few years ago, while visiting a large broadcasting station, I became interested in witnessing how building fixtures, automobiles, *etc.*, became crude receiving sets in the vicinity of the station, sometimes giving out very good reproductions of programs which were being broadcast. Lately, I have been told that it is a matter of common knowledge among radio engineers that very many different kinds of objects, under proper conditions, serve as receiving sets in the vicinity of powerful sending stations. Engineers explain that the powerful electromagnetic waves from the sending station are rectified by suitable objects, especially metallic structures, and are transformed into true sound waves.

The observer of a meteor is almost certain to be surrounded by an environment made up of objects, some of which are capable of rectifying the electromagnetic waves and transforming them into sound. While looking over these notes, which had been written some months ago, and attempting to find references to such phenomena in older writings, I was surprised to find the following statement from the late Dr. J. A. Udden, in his paper on "The Texas Meteor of October 1, 1917," *Univ. of Texas Bull.*, No. 1772, 46-7, 1917, in which he seems to suggest the very same principle without naming the agency:

"The first suggestion is that these sounds were merely subjective associations, brought by the rapid motion of the meteor. They could not have been produced as real sound waves in the air by the meteor directly, arriving, as it appears, simultaneously with its light. But the reports are couched in such reasonable language and come from so many entirely creditable sources that I am inclined to believe the phenomenon is worth future attention and consideration. In furtherance of such an attitude, I have called attention to this reported sound in *Science* for December 21, 1918 (pp. 616-17). Dr. F. M. Pottenger, of Monrovia, California, has later informed me that some thirty-seven years ago he saw, in company with his brother one evening, a great meteor in Indiana. He says that their attention was called to something unusual, first by a hissing sound, such as was noted in association with this fall, and then by a bright light, which cast shadows on the

ground. Upon looking to the northeast, they then saw a large ball of fire passing across the heavens.

"If these observations are not subjective, the cause of the sound may perhaps be sought in ether waves that, on meeting the earth or objects attached to the earth, such as plants or artificial structures, are in part dissipated by being transformed into waves of sound in the air. Whether such a transformation of energy is possible, it is not my purpose here to discuss. The suggestion is merely made for what it is worth."

We think it probable that radio has furnished a clue as to the nature of these peculiar phenomena which many workers on meteors and meteorites have encountered. We may recognize at once the probability that a meteorite arriving from space will carry a very different electrical potential from that of the earth. It has been suggested that this difference may run as high as several million volts. With an enormous P.D. and the extremely rapid deceleration due to friction, it would seem that we have a very favorable set-up for the sending out of powerful electromagnetic waves. Meteorites invade the atmosphere at velocities now estimated to range from 7 to 80 mi./sec. G. V. Schiaparelli has calculated that the resistance of the upper atmosphere is such that a meteorite which enters it from space with a velocity of 44¾ mi./sec. would, by the time it reaches a level where the pressure of the air is equal to one millimeter of mercury, be reduced to a speed of 3⅛ mi./sec. This diminution would be accomplished at an elevation of some 27 or 28 miles. Meteorites often continue luminous far below this elevation, certainly to a level as low as 8 miles and probably lower. The tremendous energy-transformation represented by such rapid deceleration must be a source of much ethereal disturbance. In view of the preceding facts, it seems probable that an invading meteorite becomes in effect a very powerful sending station, so powerful, in fact, that many different kinds of physical objects in our environment may serve as crude receiving sets.

The noise reported as occurring simultaneously with the passage of a meteor is entirely different from those explosive detonations (true aërial sounds) which arrive some minutes later. The former is described usually as a "swishing," "humming," "hissing," "whining," "rustling," or "crackling" sound. Often the sound has been compared to that caused by plunging a heated iron into cold water. In some cases it has been likened to the sound of frying bacon. Mr. J. H. Bruer (see "The Great Meteor of March 24, 1933," *loc. cit.*, p. 303), who was working inside a building and had not known of any light phenomena, thought he heard an airplane. Only when he walked to the door to see the airplane did he know of the strange light which was traversing the bright midday sky. Detonations arrived some *three minutes* later!

The writer has finally become convinced of the reality of such sound where the environment of the observer is favorable. He suggests that *ethaërial* (a contraction from *ether* and *aërial*, pronounced, ēth-ā-ē′-rĭ-ăl) be used as a designation for sound produced by the natural transformation of ether waves into audible sound.

Report of the Sixth Annual Meeting

By Lincoln La Paz, *Secretary pro tempore*

The Sixth Annual Meeting of the Society was held in conjunction with the One Hundred-Third (First Virginia) Meeting of the American Association for the Advancement of Science on December 29 and 30, 1938, at the Mosque, in Richmond, Virginia. The following ten members were in attendance at one or more of

the sessions of the Society, which were open also to and were well attended by the public:

D. M. Barringer, Jr. (Philadelphia, Pa.), Charles E. Johnson (Richmond, Va.), Joseph Kaplan (Los Angeles, Calif.), Lincoln La Paz (Columbus, Ohio), H. A. Meyerhoff (Northampton, Mass.), Mrs. Addie D. Nininger and H. H. Nininger (Denver, Colo.), G. Edward Pendray (New York, N. Y.), William F. Prouty (Chapel Hill, N. C.), and Beaufort S. Ragland (Richmond, Va.).

The number of papers presented (twenty-five) was the largest in the history of the Society. Fourteen of these papers were presented personally by their authors. Probably the outstanding feature of the meeting was the joint symposium, held on the morning of December 29, with Section E (Geology and Geography) of the Association and the Geological Society of America, which was participated in by several outstanding authorities in the fields of geology and meteoritics. Eight papers were delivered at this symposium, five personally by their authors. The program of the meeting and the list of papers read are given hereafter.

[No meeting of the Council was held, since the only member of the Council in attendance was the President of the Society.]

PROGRAM OF THE SIXTH ANNUAL MEETING
President H. H. Nininger presiding

Thursday, December 29

9:00 A.M., Lounge A, Mosque: Joint Session with Section E (Geology and Geography) of the American Association for the Advancement of Science and the Geological Society of America, for consideration of the subjects, "Meteorites and Meteorite Impacts" and "The Carolina 'Bays'." Dr. H. A. Meyerhoff, the Secretary of Section E and a member of the Society, called the meeting to order and, after certain introductory remarks, asked President Nininger to take the chair. In the absence of the Secretary (Dr. R. W. Webb), the President requested Dr. Lincoln La Paz to serve as Secretary *pro tempore*. The presence and pertinent comments of Messrs. D. M., Jr., and B. Barringer, the sons of Daniel Moreau Barringer, one of the chief exponents of the meteoritic origin of the Canyon Diablo crater, added much to the interest of this highly instructive joint session.

2:00 P.M., Chanters Room, Mosque: Session for Papers, concluding with the address of the President on the "World Outlook for Meteoritical Research."

Friday, December 30

10:00 A.M., Lounge A, Mosque: Session for Papers.

The display of meteoritic specimens and literature and, particularly, of a diamond in a Canyon Diablo iron under the microscope, arranged by Dr. and Mrs. Nininger, was one of the most striking and popular exhibits in the Science Exhibition in the Banquet Hall of the Mosque.

LIST OF PAPERS READ AT THE SIXTH ANNUAL MEETING

*†§1. THE METALLURGICAL INTERPRETATION OF THE STRUCTURES FOUND IN METEORITIC IRONS, *Gerhard Derge*, Carnegie Institute of Technology.

*†§2. THE DISTRIBUTION OF THE RECOGNIZED METEORITES OF NORTH AMERICA, *Lincoln La Paz*, Ohio State University.

†3. STUDIES OF METEORITE CRATERS, *Clyde Fisher*, Hayden Planetarium, New York, N. Y. (read by H. H. Nininger; supplementary remarks by D. M. Barringer, Jr.).

*†§4. SOME GEOPHYSICAL DATA ON THE METEORITE CRATER IN ARIZONA, *Hans Lundberg*, Toronto, Ontario, Canada.

*†§5. ORIGIN OF THE ELLIPTICAL BAYS OF THE ATLANTIC COASTAL PLAIN, *William F. Prouty*, University of North Carolina.

†§6. POSSIBLE LATE CRETACEOUS ORIGIN OF THE CAROLINA "BAYS," *Frank A. Melton*, University of Oklahoma (read by title).

†7. ELLIPTICAL BAYS IN HORRY COUNTY, SOUTH CAROLINA, *C. Wythe Cooke*, U. S. Geological Survey, Washington, D. C. (read by H. A. Meyerhoff).

*†8. PLEISTOCENE SHORELINE FEATURES IN SOUTHEASTERN VIRGINIA, *Watson H. Monroe*, U. S. Geological Survey, Washington, D. C.

*9. RECENT ADVANCES IN OUR KNOWLEDGE OF THE EARTH'S UPPER ATMOSPHERE, *Joseph Kaplan*, University of California, Los Angeles (contributed by invitation to the program of the meeting).

*‖10. METEORITIC DUST AND THE PRODUCTION OF METASTABLE NITROGEN MOLECULES, *Joseph Kaplan*.

*11. CRITERIA FOR ESTIMATING THE POPULATION OF A METEORITIC SHOWER, *Lincoln La Paz*.

*12. WORLD OUTLOOK FOR METEORITICAL RESEARCH: Address of the President, *H. H. Nininger*, Colorado Museum of Natural History and American Meteorite Laboratory, Denver.

13. TAENITE, *John Davis Buddhue*, 99 S. Raymond Av., Pasadena, Calif. (read by Lincoln La Paz).

*14. NEW METEORITES, *Addie D. Nininger*, American Meteorite Laboratory, Denver, Colo.

*15. THE PROBABILITY OF THE FORTUITOUS OCCURRENCE OF A RECTILINEAR CHAIN OF "BAYS," *Lincoln La Paz*.

*16. THE AGE OF THE PULTUSK, POLAND, STONES, *Lincoln La Paz*.

*17. SUB-SOIL METEORITES, *H. H. Nininger*.

18. THE TREE METEORITES OF LA PINE, OREGON, *J. Hugh Pruett*, University of Oregon (read by Lincoln La Paz).

*¶19. METEORITIC SOUNDS FROM ETHER WAVES, *H. H. Nininger*.

20. THE WILLAMETTE, OREGON, METEORITE IN HISTORY, *Betty Jane Thompson*, University of Oregon (introduced by J. Hugh Pruett and paper read by H. H. Nininger).

‡21. THE ABNORMAL PENETRATION OF THE NORFORK, ARKANSAS, IRON, *Lincoln La Paz* (read by title).

22. NEW SIDERITES FROM KENTUCKY, *David M. Young*, University of Kentucky (read by title).

‡23. THE PANTAR, LANAO, PHILIPPINE ISLANDS, METEORITE, *H. H. Nininger* (read by title).

‡24. METEORITICAL PROOFS OF THE EARTH'S MOTIONS, *Samuel Herrick, Jr.*, University of California, Los Angeles (read by title).

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*Papers thus marked were presented personally by their authors.

†Papers thus marked were delivered at the joint symposium of the Society, Section E (Geology and Geography) of the American Association for the Advancement of Science, and the Geological Society of America, held on Thursday morning, December 29, on the topics, "Meteorites and Meteorite Impacts" and "The Carolina 'Bays'."

‡Papers thus marked were read by title, since they had been published in full in the *C.S.R.M. immediately before* the date of the meeting. See the November, 1938, issue for paper no. 21 and the December, 1938, issue for nos. 23-5.

§Abstracts of papers nos. 1, 2, 4, 5, 6, and a paper on "Observations and Suggestions Regarding Meteorite Craters," by H. H. Nininger, are contained in *Bull. Geol. Soc. Am.*, **49**, No. 12, Pt. 2 (Dec. 1, 1938), on pp. 1948, 1952, 1953, 1957, 1954, and 1956, respectively.

‖Published in full in the *C.S.R.M.* for January, 1939.

¶Published in full in the *C.S.R.M.* for February, 1939.

‡25. Recording the Time and Place of Fall and the Designation of Meteorites, *Frederick C. Leonard,* University of California, Los Angeles (read by title).

Meteor Trails and Meteor Trains

A clear distinction should be made between *meteor trails* and *meteor trains.* A *meteor trail,* which is essentially a photographic impression, is simply the track or streak left by a moving meteor on a photographic plate or film and is due, of course, to the motion of the meteor across the field of view. A meteor trail is analogous to—although obviously not attributable to the same cause as that of—the star trails which result from photographing stars with a stationary camera—*i.e.,* an apparatus which is not compensated for the effect of the earth's rotation.

A *meteor train,* on the other hand, is the self-luminous phenomenon which is left occasionally in the wake of a brilliant meteor, and, instead of being merely an optical illusion, like a meteor trail, is a real, physical manifestation which may be observed entire, either visually or photographically, at any instant of its existence. The photography of a meteor train is likely to be attended by considerably more difficulty than is that of a meteor trail, unless the train be very bright and persist for some time. However, the direct or spectrographic registration of a meteor train is of great scientific value, and may lead to important knowledge concerning the physics and the chemistry of these comparatively rare phenomena. F.C.L.

The Publications of the Society

Copies of the back numbers of the *C.S.R.M.,* namely Nos. 1, 2, and 3 (of Vol. 1, 1935-37), are becoming increasingly difficult to supply, but will be sold as long as they last at the rate of $2.00 a copy. The stock of the first two numbers is rapidly nearing exhaustion. Vol. 2, No. 1 (68 pp., 1938), has just issued from the press. Copies of this number also are obtainable for $2.00.

In addition, the Society is still able to furnish copies of the late Dr. O. C. Farrington's treatise on "Meteorites" (233 pp., 1915) at $3.50 per copy plus 20 cents for postage.

Orders for any of the aforementioned publications should be addressed to the *Secretary,*

Robert W. Webb.

Comet Notes

The "deadline" for *Comet Notes* being at hand, Professor Van Biesbroeck wrote that, due to the scarcity of comets, there would not be any "Notes" for the February issue. However, just before going to press, Comet Cosik-Peltier was discovered. At the request of the Editor, the undersigned has summarized the information at hand concerning the new comet.

Our first word of the discovery was through the medium of *Harvard Announcement Card* No. 467, which is dated January 20, 1939, and reads as follows: "New Comet.—A telegram received late last evening from Mr. L. C. Peltier of Delphos, Ohio, announces his discovery of a comet in the following position:

$$\alpha = 21^h\,20^m; \quad \delta = +28°; \quad \text{magnitude 8.}"$$

Harvard Announcement Card No. 468 (dated January 23), however, reveals that the new comet had been observed in Russia by Cosik, and then more accur-

ately by Beljawski, a half day earlier than its discovery by Peltier in Delphos. This *Announcement Card* designates the new object as "Cosik-Peltier Comet," so that the independent discoverers, Cosik and Peltier, are both granted recognition. The *Card* states, "The comet has a nucleus, and a tail more than one degree in length," and lists six positions, the latest on January 23.

Harvard Announcement Card No. 469 (January 24), lists elements and ephemerides by Cunningham, and by Maxwell and Grosch, as follows:

ELEMENTS

	Cunningham (a)	Maxwell & Grosch (b)
T =	1939 Feb. 6.3904	February 6.16
ω =	168° 21′	168° 00′
Ω =	289 17	289 32
i =	63 15	63 6
q =	0.71856	0.720
Dates of observations:	January 21, 22, 23	January 21, 22, 23

EPHEMERIS

1939 U.T.	R.A. (a)	R.A. (b)	Decl. (a)	Decl. (b)	(a) ρ	(a) r	Mag*
	h m s	s	° ′ ″				
Jan. 25.0	21 55	03	+25 54				
29.0	22 26 27	32	+23 09 09		0.66	0.74	7.3
Feb. 2.0	23 01 21	32	+18 60 58		0.61	0.72	7.0
6.0	23 38 26	47	+13 15 11		0.57	0.72	6.8
10.0	0 15 49		+ 6 07		0.54	0.72	6.7
14.0	0 51 31		— 1 40		0.55	0.73	6.9

*Magnitude was assumed to be 8.0 on January 22.14, and the $\rho^2 r^6$ formula was used.

It will be noted from the above data that the comet passes perihelion on February 6, at a distance from the sun of 66,740,000 miles. The minimum distance of the comet from the earth will be 51,080,000 miles, reached around February 10. It is predicted that the brightness of the comet will increase until about February 10, when its stellar magnitude will be 6.7.

The first opportunity for observation of the new comet at the Goodsell Observatory occurred on the evening of January 26. Examined with the aid of the 16-inch visual refractor, the comet showed a round nucleus with no sharp central condensation, and a smoothly flowing tail visible for half a degree. With a telescope of smaller focal ratio, the tail would probably appear at least a degree in length. Estimates from photographs taken January 26, with isochromatic plates and a yellow color filter, place the visual magnitude of the nucleus around 8.5 on this date. The integrated visual magnitude of the entire head of the comet (only the nucleus appeared on the photographs) would doubtless be the equivalent in brightness of a 7 to 7.5 magnitude star.

R. S. ZUG.

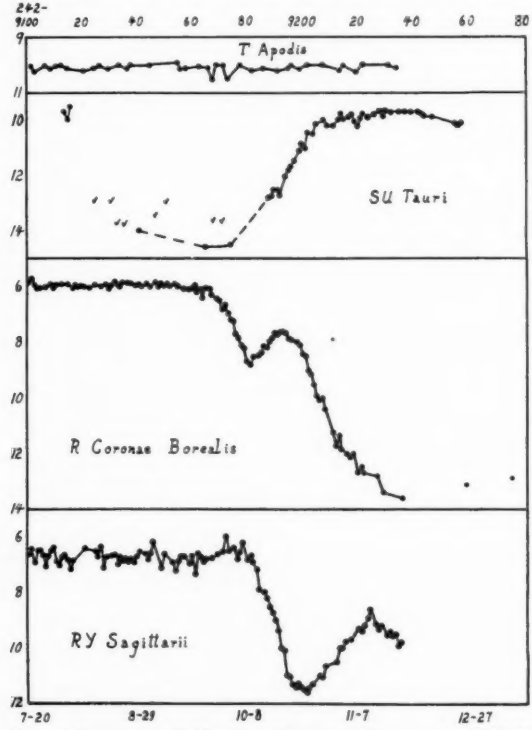
Goodsell Observatory, Northfield, Minnesota.
January 27, 1939.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Four R Coronae Borealis Type Variables: In the Variable Star Notes for November, 1938, attention was called to the recent "acting up" of three of the four well-observed R Coronae Borealis type variables, with a figure showing their light curves from January, 1930, to November, 1938. Since that time more nearly complete data have been received from observers in all sections, and it is therefore possible to illustrate better the more recent activities of these stars. In the accompanying figure each point is the daily mean of all the reported observations.



LIGHT CURVES OF R CORONAE BOREALIS VARIABLES, 1938-39
(*For* T Apodis *read* S Apodis.)

S Apodis, 14597*1*, is the only one of the four which remained at constant brightness during the interval: at magnitude 10.08, with an average deviation of a tenth of a magnitude. With only slight fluctuations, S Apodis has been at max-

imum since August, 1935. At minimum this star decreases in light to below the fourteenth magnitude.

SU Tauri, 054319, the first of these stars to show evidence of recent activity, began its decrease probably early in August, 1938, and, although the descent was insufficiently observed, it appears to have reached magnitude 14.6 on September 22. By the middle of October the variable had definitely risen to the twelfth magnitude, subsequently increasing steadily to normal maximum, magnitude 9.7, about November 15. It has remained essentially at this magnitude, with a tendency to become slightly fainter, if observations near December 22 are to be relied upon.

R Coronae Borealis, 154428, may be said to have begun its latest decrease in brightness on September 12, very gradually at first, then more rapidly, until magnitude 8.8 was attained on October 8. Almost immediately the brightness began to increase, reaching magnitude 7.6 on October 20. Instead of ascending further to normal maximum, the star speedily and steadily decreased in magnitude to 13.6 on December 2. Unfortunately the region was by that time very unfavorably placed for observation in the western sky and information as to its present status is so far lacking.* The present minimum has no resemblance in form to that of 1935, the last observed decrease in light.

Early in October, RY Sagittarii, 1910*33*, started on its downward trend from magnitude 6.5 to a magnitude of 11.6 on October 28—a decrease of five magnitudes in three weeks. It remained at minimum for three or four days only, whereupon it rose to magnitude 8.6 on November 21, immediately fading away until, on December 1, it had reached the tenth magnitude.

Regarding the forms of light variation of these stars in the near future, almost anything can happen. It was shown by T. E. Sterne a few years ago that R Coronae Borealis could well be considered the most ideally irregular of all variable stars, with occurrences of minima ranging from a few weeks to ten years, and with no indication as to when a new cycle would start or how long it would last. If the explanations by Berman and O'Keefe concerning the cause of variation in these stars are to be given credence, it would seem that obscuration of the star itself by some such material as carbon might account for the irregular diminution in light.

Variable Stars at the American Astronomical Society Meeting: Of the forty odd papers read at the New York meeting of the American Astronomical Society, only nine dealt directly, or indirectly, with variable stars. Three of these papers, on the complex theory of motions in eclipsing binaries, were presented by Drs. Russell, Sterne, and Kopal; two others had reference to spectral studies: the *Infrared Spectrum of Gamma Cassiopeiae* by Dr. Ernest Cherrington, Jr., and the *Spectrum of Upsilon Sagittarii* by Dr. D. B. McLaughlin. The question of the probable thickness of the Milky Way, based upon studies of cluster-type Cepheids, was discussed by Dr. Shapley; and Dr. S. Gaposchkin read a paper on a *New Russell Diagram*, which was constructed from data obtained from eclipsing binaries. The only papers dealing with direct observational material were by Miss H. H. Swope, who showed some interesting light curves of peculiar variables in Milky Way Field 186 that are involved in varying densities of obscuration; and a paper by Dr. J. S. Hall, in which he showed results of photoelectric observations of Algol in red and in blue light. It is of interest to note the changing character of papers on variable stars as compared with those presented a decade or two ago

*An observation secured on January 11 gives the magnitude at 12.9, probably increasing.

when emphasis was placed upon the observational data, in contrast to the present theoretical papers. This is, of course, what one would expect from the ever-increasing accumulation of data.

Harvard Monograph, Number 5: This monograph, the combined efforts of Dr. Cecilia Payne-Gaposchkin and Dr. Sergei Gaposchkin, treats of variable stars in a comprehensive manner, strengthened throughout by extremely clear technical discussion. Some fifty pages are devoted to tables containing fundamental data on all types of variables, and there are over twenty figures depicting the several types of light variation found in these stars.

The introductory chapter presents a general survey of variable star problems, describing, in particular, types of stellar variability, with an explanation of general classifications, and refers to lists, bibliographies, and ephemerides of variable stars.

The authors have arranged the subsequent chapters under four classifications of variables. First, the Geometrical Variables, those stars which vary not of themselves but only because their geometrical positions with respect to the observer cause their light to change to a greater or less degree, in short or in long periods. Dr. S. Gaposchkin, a recognized authority on eclipsing binaries, is mainly responsible for this chapter. Next are treated the Intrinsic Variables, about which much remains to be learned. This group, known chiefly as The Great Sequence, includes the so-called long-period variables, the Cepheids, and the semi-regular variables. The irregular red variables are the last of the Intrinsic Variables to be discussed. Then follow the Cataclysmic Variables, such as novae and the SS Cygni and R Coronae Borealis type stars.

Extrinsic Variables, those stars which are involved in nebulosity, and the so-called spectrum variables, are treated somewhat briefly, while the final chapter considers the technique of discovery and the observation of variables, as well as a discussion of observations. It is but natural that the authors should stress photographic technique more than visual, since it is in this field that they have been principally engaged.

The publication of this monograph fills a long-felt need, especially to students of variable stars. Observers the world over will find it a ready compendium of important information; and it gives a comprehensive picture of the problem as it stands today.

Confirmation of Variability of — Draconis, 195377: The star, tentatively designated as 90.1934, — Draconis, 195377, and discovered by Morgenroth from photographs taken at Berlin-Babelsberg, proves to be a variable of short period with a visual range between magnitudes 12.0 and 14.6. Fairly continuous observations made by the A.A.V.S.O. during the past four months indicate that ten maxima were observed, yielding a mean period of approximately 12.5 days. There does not appear to be enough regularity in cycles to classify the star as a Cepheid; perhaps the variations resemble more nearly those of Z Camelopardalis. Morgenroth classified the star as long period, but his plates may have been too far separated in time to reveal the short-period characteristics. The photographic range was cited by the discoverer as from 13.5 to less than 15.5, which indicates a large color difference, unless we assume a large scale error between the assumed visual and photographic magnitudes. The star certainly should be included in the current list of galactic variables, and deserves special attention on the part of observers, both visual and photographic.

Observers and Observations during December, 1938

Observer	Var.	Est.	Observer	Var.	Est.
Ahnert	46	287	Kelly	10	11
Albrecht	8	8	Kirkpatrick	23	61
Baldwin	98	155	deKock	69	170
Ball, A. R.	25	36	Koons	7	8
Ball, J.	17	23	Kotsakis	9	59
Bappu	34	165	Kozawa	14	29
Blunck	15	18	Lundquist	2	9
Bouton	55	83	Maupomé	35	38
Brocchi	12	12	McLeod	29	62
Buckstaff	12	30	Meek	53	521
Callum	35	56	Millard	25	29
Christman	17	17	Neale	2	2
Cousins	21	77	Needham	28	32
Dafter	11	30	Parker	16	18
Davis	4	5	Peltier	205	249
Diedrich	16	16	Prinslow	14	14
Economou	9	24	Purdy	11	14
Ensor	46	59	Rademacher	2	2
Escalante	110	170	Recinsky	13	23
Evans	19	19	Rosebrugh	12	56
Ferguson	5	8	de Roy	15	40
Fernald	31	50	Ryder	16	16
Franklin	23	31	Seely	16	32
Friton	9	30	Seibel	4	4
Gregory	21	56	Shultz	15	15
Halbach	68	76	Sill	59	59
Hamilton	15	25	Smith, F. P.	20	28
Harris	9	9	Smith, F. W.	3	4
Hartmann	177	365	Smith, J. R.	8	8
Herbig	154	871	Smith, L.	12	12
Hiett	18	52	Topham	6	8
Hildom	36	59	Webb	38	41
Holt	52	52	Weber	25	25
Houghton	61	153	Woods	12	51
Howarth	17	18	Yamasaki	21	21
Jones	73	170	Zahner	5	5
Kanda	2	12			
Kearons	77	141	Total observations		5244

January 12, 1939.

Notes from Amateurs

Some Changes in the Lunar Crater Macrobius

The crater, Macrobius, is a rather conspicuous crater northeast of the Mare Crisium. It is 42 miles across and 13,000 feet deep (see Webb's "Celestial Objects," page 87). This crater was picked for observation because it was a conspicuous crater which had never been investigated before, and because it was near the western limb of the moon, and, consequently, could be followed through its changes without staying up past midnight. The Olcott 5-inch telescope was used. Most of the time a power of 150 was used, but occasionally a power of 210 was used. The observations were carried on from June 2 to November 8, 1938. About twenty drawings were secured, showing the crater during the period from sunrise to sunset.

When the shadows disappear at sunrise, the bottom of the crater is of a uniform light-grey color, except for some white spots which represent, apparently, the sunlit slopes of ridges or other elevations. At phase 7 days, a very dark grey band appears across the center of the crater. This dark area rapidly widens until, by the time the moon is 9 days old, it covers the north half of the bottom of the crater. In the meantime the craterlet on the east wall has become dazzlingly bright as its white lining and bottom come out of the shadows. The wall at the south end of the crater has become invisible. At phase 11 days, the dark area has spread into the south half of the crater. This is the greatest extent of the dark area. At full moon, the dark area is on the wane, being confined to the northern half of the crater, where it does not extend all the way to the northernmost tip. The craterlet is less conspicuous and the crater's wall is visible all around. The dark area has disappeared at phase 15 days and from then on the bottom of the crater is of a uniform light grey, the same as it is during the sunrise phases.

The appearance of and the changes in the dark area can not be caused by shadows because the dark area is largest a little after the sun is directly overhead as seen from the crater. This is the time when that part of the moon's surface would be hottest. The fact that the dark area is most conspicuous at the time when the crater would be expected to be hottest, coupled with the fact that its development is slower than its disappearance, would indicate that this dark area is due to something more or less resembling vegetation.

Examination of the photographs of the late W. H. Pickering's "Photographic Atlas of the Moon" (*Harvard Annals*, Vol. LI) confirms these changes as far as the photographs cover the subject. Apparently, the contrast is less in photographic than in visual light.

NOAH W. MCLEOD.

Christine, North Dakota, November 13, 1938.

The New Haven Amateur Astronomical Society

The second anniversary of the New Haven Amateur Astronomical Society was observed on January 7 with an open meeting in Sage Hall addressed by Dr. Robert H. Baker of the University of Illinois, his subject being "Problems of the Milky Way." He stated that the universe presented two major problems, first its construction and secondly its evolution. The evolution of the universe has had many hypotheses and theories which were accepted and flourished for a time but, as greater knowledge of the laws governing celestial bodies was obtained, one after another of these theories has yielded its place to a new one. The original "Earth Center" idea was replaced by the Copernican theory of the "Sun Center" system which later was elaborated by Laplace's Nebular Hypothesis in 1796. This hypothesis was generally accepted and served to meet the conditions for a number of years, but as time went on and new facts were discovered it required some adding to or modification as it was found to be lacking in many respects. In 1895 Dr. Forest Moulton came forward with a new theory known as the Planetesimal Theory which radically departed from Laplace's theory but this theory in time was found also to be incomplete and wanting in many details. In 1916 the "Tidal Theory" was put forth but even that theory is now being severely criticised by some astronomers in view of its conflict with certain known laws.

Dr. Baker stated that there was a marked non-uniformity in the distribution of stars in the Galaxy and that they persisted in crowding toward the region of the Milky Way, which condition was first discovered by Sir William Herschel who described our galaxy as an enormous cartwheel with our sun and its attending planets

near the center. More recent observations have proved that our solar system is not near the center but about one third of the way out from the center.

Dr. Baker discussed at length the dark nebulae which are so abundant in the Milky Way region and he gave some very interesting information regarding the extent, distance, and characteristics of them, and showed many beautiful slides to illustrate his descriptions and statements.

This meeting climaxed two years of progress of the Society and was greatly appreciated by the large number present.

After the meeting a reception was held at the home of Dr. Brouwer (of the Yale Astronomical Staff) and all had an opportunity to meet and talk with Dr. Baker who was very ready to answer the many questions put to him as only amateurs can.

Dr. Baker was accompanied by Mrs. Baker and a thoroughly enjoyable and profitable evening was spent by all.

F. R. BURNHAM, *Secretary.*

January 17, 1939.

Cleveland Astronomical Society

As the winter season progresses we continue with a good lecture by some famous astronomer at every regular meeting. At the Physics Lecture Room, Case School of Applied Science, we had, as speaker, Robley C. Williams, Ph.D., Assistant Professor of Astronomy at the University of Michigan. He gave an illustrated lecture on "The Color and Temperature of Stars." This lecture was open to the public and many who are not members of the society availed themselves of the opportunity to hear an authority on the subject. Since little work is attempted in this field by the amateur astronomer, the subject, ably handled, proved of great interest.

The first social evening of the new year was held at the home of one of our members, Miss Helen Focke, 2517 Wellington Road, Cleveland Heights. The evening began with a showing of astronomical motion pictures. This was followed by a social hour and refreshments. These meetings are always a great success and members become better acquainted. There is little activity in the telescope-makers section this winter. In fact, as far as we know, the only member who is using his reflector to good advantage is Russell who has a good report for January under Variable Star Notes from the American Association of Variable Star Observers. It seems that most of our members use binoculars or small refractors for their observations. Seeing conditions over the greater Cleveland area are always bad at this time of year which may account for lack of interest in the grinding of large mirrors.

DON H. JOHNSTON.

Euclid Beach Park, Cleveland, Ohio.

Louisville Astronomical Society Notes

The Louisville Astronomical Society's 1938-39 season has started off with an active and diversified program.

In October the annual business meeting was held with the election of officers for the coming year. Mr. J. J. Burke is the new president; Mr. Stanley F. Thorpe, vice-president, and Miss Mary Eberhard was re-elected secretary-treasurer. The speaker at this meeting was Mr. Lewis P. Aker, retiring president, whose subject was "Planetary Gossip." As the November meeting fell on the fifteenth of the month, which was the 200th anniversary of the birth of Sir William Herschel, the program was arranged in commemoration of this event. Herschel, having been

a musician as well as an astronomer, a short musical prologue was planned with Madam Cara Sapin accompanying Miss Virginia Williams in a number of vocal selections appropriate to the occasion. Following the music, Mr. Charles G. Strull, chairman of the Education Committee of the Society, read a comprehensive paper on "Astronomy before Herschel and after." The program closed with Mr. P. A. Hebebrand reading a poem, which he had written, entitled "Sir William Herschel." The December meeting was specially enjoyable. One of our members, Miss Mary Pressley Smith, talked on "Stars of the Bible," quoting many lovely and inspiring passages referring to the wonders of the heavens. Our guest speaker was Mr. Frederick Weygold, who has made quite an extensive study of the American Indians, having lived among the Blackfeet Tribe about twenty years. Mr. Weygold's talk on "Astronomy of the North American Indian" was most entertaining and interesting, especially regarding their impressions of the sun and earth and how they likened the sun to a great bird, because, as they thought, it flew over and around the earth. And, as to them the eagle was the largest and flew highest of all birds, their symbols of the sun represented the rays as eagle feathers. The earth they described as a rectangle, with the prevailing winds coming from the four corners of the earth. Mr. Weygold illustrated his lecture with several articles from his extensive collection and, at the close of the program, exhibited buffalo robes and a miniature tepee which were decorated with symbols based mostly on natural phenomena.

The Society is pleasantly anticipating the January meeting as Mr. Latimer J. Wilson of Nashville, Tennessee, is to be the speaker of the evening. Mr. Wilson is an honorary member of the Louisville Society and visited here in 1936, at which time he talked on "Amateur Photography in Astronomy" and showed slides of many of the beautiful pictures which he had made. His subject for the coming meeting is "Stories Told in Lights," and we feel that a treat is in store for us.

Our 20-inch mirror is now ready for polishing and plans are under way for the building of an observatory in the near future, we hope. The "Open House" meetings which are held each year during the summer months are well attended and much interest is shown. At these meetings, members set up their telescopes in the city parks and the public is invited to observe. We feel that an observatory in our city will be appreciated.

MARY EBERHARD, *Secretary.*

January 7, 1939.

General Notes

Due to unforeseen delays, it has been impossible, as yet, to adopt the new schedule mentioned on page 595 of the December, 1938, issue. However, we still have the new schedule as our goal and hope to attain it in the near future. EDITOR.

Professor Harlow Shapley, director of the Harvard College Observatory, has been elected a member of the section of astronomy, and Prince Louis-Victor de Broglie, of the Institut Poincare, Paris, a member in the section of physics, of the Royal Swedish Academy of Science. (*Science,* January 6, 1939.)

The Rittenhouse Astronomical Society of Philadelphia held a regular meeting of the Society on Friday, January 13, in the Hall of The Franklin Institute, Benjamin Franklin Parkway at 20th Street. The program consisted of elec-

tion and inauguration of officers for 1939, and an address by the Retiring President, Dr. John H. Pitman, on the subject "From Here to There."

Stellar Photometer and Colorimeter for Indiana State Observatory.—A new $1,200 instrument that will measure the brightness and colors of stars has been made for the Indiana University Department of Astronomy at the Yerkes Observatory at Williams Bay, Wisconsin. This is a type of equipment which is available only at the larger observatories and will be used exclusively for University research work.

Summary of Sun-Spot Observations at Mount Holyoke College, 1938

Month	No. of Obs.	North of Equator No. of Groups	North of Equator Av. Lat.	South of Equator No. of Groups	South of Equator Av. Lat.	Av. No. Groups at one Obs.	New Groups
January	13	16	+17°5	10	—14°5	5.62	26
February	16	11	14.3	22	11.8	7.75	31
March	17	13	17.0	18	15.6	5.35	29
April	17	14	19.1	22	15.1	7.82	36
May	20	25	18.2	30	17.0	11.10	45
June	12	20	19.3	11	10.2	7.25	24
September	6	11	17.4	6	13.8	7.50	17
October	20	24	15.9	16	13.4	6.20	34
November	13	26	15.9	19	12.3	8.15	37
December	7	10	15.0	10	10.5	7.29	17
Totals	141	170		164			296

Average number of groups at one observation 7.49
Average latitude of spots north of equator +17°1
Average latitude of spots south of equator —13.9

Most of the observations were made by Miss Edith Jones.

This record shows the average number of groups at one observation to be almost as high as in the previous year with an outstanding peak in May. Again our period of observation does not cover the still greater peaks observed elsewhere in July and August. The drop in number of new groups observed has come entirely in the northern hemisphere, though the average latitude for the reduced number is actually 0°6 farther north. In the south the zone of activity has moved towards the equator without diminishing in intensity.

ALICE H. FARNSWORTH.

John Payson Williston Observatory, January 13, 1939.

Summary of Observations of Sunspots at Vassar College Observatory during 1937-1938

The sun was observed on 124 days from September 30, 1937, to June 1, 1938, inclusive. 808 spot groups were recorded. Out of this number only 257 were new groups. About 14% were single spots which remained single while they were observable. Table I illustrates the number of groups which were followed for various lengths of time. The large number which was recorded as observed for one day only is obviously misleading. Only 25 spots were definitely of this short duration. For the remaining 58 groups no observations were made for one or more days following their recording. Table II gives the mean latitude of spots in zones 20° wide, mean latitude for each hemisphere, and the average number of new groups per day. The numbers in brackets are the numbers of new groups upon

which the mean latitude is based.

Miss Virginia Pritchett observed the sun on 119 days, and Miss Mary Peabody on 5 days.

TABLE I

DURATION OF SPOTS

Days observed	No. of groups	Days observed	No. of groups
1	83	8	9
2	31	9	7
3	27	10	13
4	16	11	12
5	11	12	10
6	16	13	2
7	19	14	1

TABLE II

	Obs. days	New grps. per day	0° to +20°	+20° to +40°	Mean Latitude N.	Mean Latitude S.	0° to −20°	−20° to −40°
1937 Oct.	21	2.4	+11(29)	+28(6)	+14.3	−17.7	−13(10)	−27(5)
Nov.	20	1.4	+12(12)	+26(1)	+12.7	−16.7	−14(11)	−23(4)
Dec.	12	2.1	+ 8(6)	+27(4)	+15.3	−20.0	−14(5)	−23(10)
1938 Jan.	13	2.4	+11(15)	+28(6)	+16.5	−14.8	−12(8)	−22(2)
Feb.	10	2.5	+12(8)	+22(2)	+14.3	−16.4	− 9(8)	−25(7)
Mar.	19	1.1	+11(3)	+23(3)	+17.1	−17.2	−12(9)	−24(6)
April	17	1.9	+14(4)	+27(7)	+22.5	−14.3	−11(17)	−24(5)
May	12	3.7	+11(15)	+25(6)	+15.0	−17.2	−12(15)	−27(8)
	124	2.1	+11.3(92)	+26.8(35)	+15.5 (127)	−16.7 (130)	−12.2(83)	−24.7(47)

Vassar College. B. G. KARPOV.

Astronomy in the "Palais de la Découverte."—As a result of the great success of the Palais de la Découverte at the Paris Exhibition of 1937, this scientific exhibit was reopened in 1938. During that year, it still aroused great interest among the visitors, so the "Ministère de l'Education Nationale" decided to continue it in 1939. The permanent status of that institution will be settled shortly. Mr. Robert Lencement, the Manager of the "Section d'Astronomie," one of the most important in the Palace of Science and the greatest exhibit ever made on Astronomy, is preparing a special paper for POPULAR ASTRONOMY, concerning the Astronomical Exhibit.

Book Reviews

General Catalogue of 33,342 Stars, prepared at the Dudley Observatory by B. Boss, S. Albrecht, H. Jenkins, H. Raymond, A. J. Roy, W. B. Varnum, and R. E. Wilson. (Published by the Carnegie Institution of Washington, 1938, 5 volumes, price $12.00.)

The publication of this catalogue completes a great enterprise begun half a century ago; its appearance has been eagerly awaited, and for some decades to come it will undoubtedly play a predominant part in studies based upon the proper motions of stars.

As early as the eighteen-seventies Lewis Boss (1846-1912), then astronomer

for the Northern Boundary Commission, set up a catalogue of standard declinations for use in latitude determinations. To get the best results Boss determined systematic corrections and weights for all the meridian circle catalogues of stars that had appeared up to that time. In 1876 he was appointed director of the Dudley Observatory in Albany, thus giving him an opportunity for extending the work to many more stars. He had made considerable progress on this task when in 1903 the founding of the Carnegie Institution and the grant to him of a substantial annual subvention, continued up to the present time, enabled him greatly to extend his plans and to embark on the determination of the proper motions in both coördinates of as many as 20,000 stars. The first fruit of this ambitious scheme was the publication in 1910 of his *Preliminary General Catalogue*, giving these data for 6188 stars, a compilation that has played a noble part in the history of our science during the past thirty years. The present work supersedes this preliminary catalogue. It has again been enlarged to include 33,342 stars and has been strengthened by the addition of recent observations, especially those carried out under Lewis Boss' direction at Albany and at San Luis in the Argentine. Lewis Boss died in 1912 and was succeeded as director of this undertaking by his son Benjamin, by whom it has now been brought to a successful conclusion. Grateful congratulations are offered to him and his collaborators, to the Carnegie Institution, and to the Dudley Observatory.

The catalogue is aimed to include all stars down to the seventh magnitude from pole to pole besides several thousand fainter ones for which the necessary observations are numerous enough and accurate enough to warrant their inclusion. Naturally there are somewhat more observations of northern stars than of southern, and naturally there are more stars in and near the Milky Way than elsewhere; but their distribution is not too far from uniform for most purposes.

The average probable error of a proper motion in right ascension is 0".007, in declination 0".006. The average probable error of either coördinate is 0".1 at the mean epoch of observation. For any other epoch, before or after this mean, the probable error is larger and for the date of issuance of the catalogue (1938.3) it amounts to 0".3 in either coördinate. This is just about the size of the probable error of *one good observation* with a modern meridian circle. The implication is obvious: all the stars in the *General Catalogue* ought now to be reobserved promptly with good meridian instruments. This will not only greatly increase the weight of the coördinates, but will appreciably strengthen the proper motions as well.

It is interesting to compare these results with those from the photographic survey now being conducted at Yale Observatory. It has turned out that a photographic position is much more accurate than a visual one with a telescope of nearly the same size. With a wide-angle camera of wide field (100 square degrees and over) of two meters focal length a single image on one plate yields a probable error of 0".16; the mean of two plates yields 0".11, and this is the probable error of a Yale catalogue position. The use of a diffraction grating and the measurement of first-order spectra enable us to extend this accuracy to bright stars as well as to faint. If this survey (which embraces about 120,000 stars) is repeated after only twenty-five years the comparison of the two will yield proper motions as accurate as those in the *General Catalogue* before us. But the photographs yield only relative positions and they are still dependent upon the meridian circle for calibrating material.

FRANK SCHLESINGER.

Yale Observatory, 1938 December 17.

Science, Technology and Society in Seventeenth-Century England, by Robert K. Merton. (*Osiris* IV (1938), Pt. 2. Whole volume, $5.00.)

We long have recognized that the scientific movement which flowered in the seventeenth century both profoundly affected and was profoundly affected by many forces other than science itself. Numerous historians have discussed its interrelations with technology, religion, philosophy, and literature. It was not, however, until the appearance of Dr. Merton's study that the broad sociological influence and foundations of seventeenth- century science were analyzed in detail. Specifically, the work considers the more significant among the "sociologically relevant aspects of certain phases of the development of science in seventeenth-century England."

In his two first content chapters Dr. Merton analyzes the various shifts in vocational interests, in technology, and in the sciences found in England during this period. An increasing interest in science and technology is paralleled by an increasing interest in the army and navy, in education, scholarship, historiography, medicine and surgery, prose writing, painting and sculpture, and by a declining interest in religion, in law and politics, and in music, poetry, and the drama. The three following chapters, "Puritanism and Cultural Values," "Motive Forces of the New Science," and "Puritanism, Pietism and Science," develop the point that in England of the seventeenth century the rise of science and technology was intimately related to the rise of Puritan protestantism. Protestants in general, both in England and on the Continent, were more inclined than were Catholics "to prefer scientific and technologic studies."

Chapters VII and VIII, "Science, Technology, and Economic Development," stress the close and mutually stimulating relationship between science and transportation and mining, two important forces in the development of England as a world power. These chapters suggest, if they do not indicate, that the industrial revolution as well as Capitalism began noticeably to develop during the seventeenth century. A further chapter, "Science and Military Technique," relates the expansion of science and technology to the growth of military armaments and improvement of military technique.

Dr. Merton closes his study with analyses of "Extrinsic Influences on Scientific Research," and "Some Social and Cultural Factors in Scientific Advance." He concludes regarding science in general as Dr. George Sarton concludes regarding mathematics, that there is no doubt that scientific discoveries "are conditioned by outside events of every kind, political, economic, scientific, military, and by the incessant demands of the arts of war and peace. Mathematics [and science] did never develop in a political or economic vacuum. However, we think that those events were only some of the factors among other factors, the power of which might vary and did vary from time to time." These two, and particularly the final chapter, are recognized by Dr. Merton as necessarily suggestive rather than definitive. As he says in discussing the various cultural and social forces which affect science, any attempt at the present time "to formulate a comprehensive sociological theory of scientific development . . . must be considered premature." Despite this handicap, Dr. Merton effectively summarizes what apparently were the major influences in technological development, and suggests a variety of problems which require more extended analyses.

The inadequacies imposed upon his study by time and space limitations are recognized and generally indicated by Dr. Merton. Such limitations prevented discussion of the connections between science in England and on the Continent, and analysis of the complex and variable norm of "utility" which led some protestants

to attack and others to espouse one or more of the developing sciences. They likewise made impossible detailed consideration of the individual and general forces which caused protestants, as protestants, to be especially favorable to science and technology. In addition, these limitations doubtless necessitated a perhaps disproportionate emphasis upon technology as compared with pure science, and with materialistic and mechanical forces as compared with concepts, ideas, and beliefs.

These unavoidable lacunae do not, however, affect the value of Dr. Merton's contribution. So substantial are its foundations and so broad its scope, that it must be consulted by all readers who seek to understand either the seventeenth century or the rise and development of modern science.

GRANT MCCOLLEY.

Smith College, Northampton, Massachusetts.

Weather Rambles, by W. J. Humphreys. (The Williams and Wilkins Company, Baltimore. $2.50.)

This little book, of 265 pages, comes from the pen of one of the world's foremost meteorologists, and is therefore authoritative in its explanations of weather lore. In addition, it possesses the charm of literary style characteristic of Dr. Humphreys' more popular writings. The book is non-technical, is printed on an excellent grade of paper, and can be recommended as a worthwhile addition to any man's library. There is no doubt that, once the book is at hand, "Weather Rambles" will be read from cover to cover. The spirit of the book can, perhaps, best be conveyed by quoting the first paragraph of the *Preface*: "Just as one enjoys roaming now and then over this or that part of the world, as whim or fancy may select, so it is pleasant, when the *wanderlust* is upon us, to ramble unconstrained hither and yon through the realm of science. And, like the Ancient Mariner, we just must tell our adventures to others. Such was the origin of "Weather Rambles," assembled here, some told for the first time, and some, by kind permission, retold with variations."

A few of the twenty-two interesting chapter titles are as follows: *Tall Tales of the Prairie Twister, Teetering on an Ice Age, Bread and Butter Meteorology, The Stuff We Call Air, How the Earth Got Its Atmosphere, Where the Rain Comes From,* and *Home Made Weather.* The text is interspersed with many fine photographs and drawings.

R.S.Z.

Fortschritte der Astronomie. (Johann Ambrosius Barth. Leipzig.)

The above title, "Advances in Astronomy," is given to a series of shorter expositions of recent astronomical developments, issued under the auspices of the Astronomische Gesellschaft, (A.G.), and the editorship of Dr. P. Ten Bruggencate. This project has been undertaken because the rapid developments in astronomy in recent years have made it practically impossible for one person to keep pace with them. The articles of this series are designed to discuss particular topics and to show their bearing upon other topics.

The first volume bears the title "Materie im interstellaren Raum," "Material in interstellar space," and was prepared by Dr. Wilhelm Becker, of the Astrophysical Observatory at Potsdam. It is an octavo, paper-bound, book of 78 pages, and the discussion is presented in five chapters. It includes a bibliography which lists 127 titles. The subject is treated with thoroughness and care which are characteristic of German works. To readers of German it will therefore prove to be a very enlightening volume.

The price stated is 7.50 marks.

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